NITROGEN

No. 1 FEBRUARY 1959

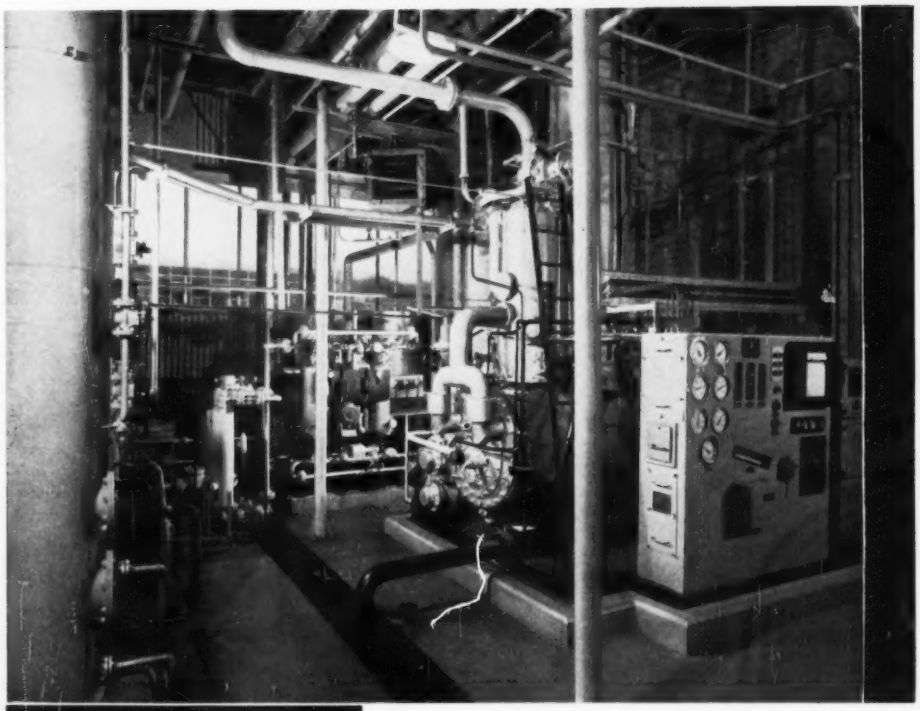
The Magazine of World Nitrogen

PUBLISHED BY

THE BRITISH SULPHUR CORPORATION LTD.
FISON HOUSE
95, WIGMORE STREET
LONDON, W.1.

Telephone : WELBECK 5500
Telegrams : SULFEX, TELEX, LONDON
Cables : SULFEX, LONDON

Printed by The Essex Chronicle Series, *High St., Chelmsford, England*



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NITROGEN GENERATOR

installed by The International Synthetic Rubber Co. Ltd.

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"NITROGEN"

THE FIRST ISSUE of the magazine "NITROGEN" marks the establishment of a service to the world nitrogen industry whereby impartial, comprehensive and accurate information on every aspect of the industry is being put at the disposal of all its sectors and all those concerned in its development and activities. Only 50 years span its establishment amongst the heavy chemicals industries and its present-day key position. Expansion of output and greater process diversification of manufacturing capacity, which has developed from the relatively rigid pattern of the pre-World War II period, have been outstanding features during the past two decades. Now the industry's rate of growth is accelerating under the twin impact of nitrogen as a fertilizer and as a basic raw material in a rapidly increasing range of new chemical processes and products. Simultaneously, the pattern of supply and demand is undergoing significant changes with producers facing freer and growing competition and trade being affected by the increasing weight of economic and political pressures. The industry's future course is determined by the varying aspects of production, technology, fertilizer and technical nitrogen usage, distribution, marketing and the affairs of companies and governments, and on this, "NITROGEN" will report and comment. The following review of the present day status of the nitrogen industry may serve as our starting point.

WORLD REVIEW

THE NITROGEN INDUSTRY represents current capital investment of about £1,000 million with an annual production capacity of some 11 million tons of nitrogen. Originally created by the need for synthetic materials in the manufacture of explosives in time of war, the nitrogen industry is now primarily geared to the chemical fertilizer market, a market which it has done much to foster and develop. To-day some 83% of the world consumption of nitrogen is in the form of fertilizer material, the remaining 17% being used for industrial purposes. Consumption of nitrogen in Europe, North America and Asia accounts for 90% of the world total and Central and South America and Africa as yet use only relatively small quantities. Western Europe, the first area to develop the extensive use of nitrogen as a chemical fertilizer, by the late 1930's accounted for one-half of the total world consumption. Since then, however, there has been considerable growth in demand in the United States and in several Asian countries and although Western Europe has doubled consumption, her share in the present world total of about 9 million tons of nitrogen a year has fallen to 29%. The most rapid development in the use of nitrogen has taken place in North America where it has increased five-fold within the last 20 years. During the same period Asia and the Communist countries of Eastern Europe have trebled their consumption.

Until the Second World War production of nitrogen other than that of organic manures was concentrated in Europe and in 1938 of a world total of nearly 3 million tons N a year, Europe accounted for 66%. Since then several factors, both political and economic, have contributed to a reduction in Europe's share to 57%. The greatest expansion in the nitrogen industry within the last 20 years has taken place in North America where production has increased nearly seven-fold, raising her share of the world total by 10% to 27%. Since 1945 the distribution of nitrogen capacity has been further affected by the erection of synthesis plants in many countries which formerly imported their entire requirements and by the efforts of the Eastern bloc countries with their planned economies to achieve the highest possible level of

United States. Escambia Chemical Corp. General view of the 200 tons per day ammonia plant at Pensacola, Florida. Left to right, Reformers, carbonate system, copper liquor system and control room.

production. Capacity in these countries now accounts for about 14% of the world total.

The outstanding development in the nitrogen industry has been the extension of the range of hydro-carbons used, whereby the industry has achieved a greater measure of flexibility in the methods of synthetic nitrogen manufacture. Although coke-oven gas remains an important source of hydrocarbon material, a steadily growing proportion of the world's nitrogen capacity is being based on the use of natural gas, fuel oil and refinery gases. With this development the necessity to site the nitrogen plants in the vicinity of economic sources of coal and coke is no longer overriding and has enabled the industry to build its production facilities in a favourable position in relation to its markets as well as raw material supplies. Simultaneously, there has been an increase in the number of nitrogen products and their applications and the soaring production of urea, ammonium nitrate and a number of specialised nitrogenous materials for use both in agriculture and industry is evidence of this trend.

With the expansion of production, the volume of trade in nitrogen has grown steadily during the last 15 years and now totals nearly 2 million tons N a year, two and a half times the pre-war level. The most important developments in the pattern of this trade, virtually confined to fertilizer materials, have been the emergence of North America as a net exporting area, for shipments of large quantities of fertilizer under foreign aid programmes, and the strengthening grip of Japanese exports on the Asian market. Despite these developments, Western Europe has retained her position as the principal exporting area of nitrogen fertilizers and still accounts for about 65% of the world total.

CONSUMPTION

Agriculture

Since the end of World War II the nutrient ratio for fertilizer materials in most countries has moved sharply in favour of nitrogen and towards the ratio of 1 : 1 : 1. In Western Europe, which has a higher consumption of fertilizer than any other area, this feature has been less pronounced than in the majority of the rapidly expanding overseas markets.

Nutrient Ratios in Western Europe

	N	*P*	*K*
1936-38	1	1.58	1.36
1949	1	1.41	1.26
1953	1	1.26	1.36
1955	1	1.18	1.24
1957	1	1.14	1.16

The varying requirements of consumers and the ability of producers to manufacture some materials more economically than others have resulted in the production of a growing range of nitrogen fertilizers. Ammonium sulphate, which now accounts for 30% of the world total, is still consumed in greater quantities than any other nitrogenous material, but is now being strongly challenged by ammonium nitrate, which is being used in steadily increasing quantities. These two fertilizer materials account for over one-half of world consumption. Ammonia, applied directly to the soil in anhydrous form or mixed with water, accounts for nearly 10% of the total nitrogen consumed in agriculture, but its use is still largely confined to the United States. Calcium nitrate and calcium cyanamide each make up about 5% of the world total and are closely followed by urea and sodium nitrate. Consumption of calcium nitrate, calcium cyanamide and sodium nitrate has, however, risen at a much slower rate than urea.

Western Europe

High population density and constantly increasing industrialisation have necessitated

great intensity of agricultural production per unit of land in Western Europe and has provided the basis for a large fertilizer market. Among other factors which have influenced the most recent growth of nitrogen consumption in Western Europe have been the fertilizer subsidies paid to farmers in several countries and the need for her very substantial and steadily increasing production capacity to find an outlet.

Western Germany has the highest consumption of the countries of Western Europe with a total of 540,000 tons a year, but the greatest rate of increase in consumption, of Western Europe the increase in the use of nitrogen since 1939 ranges from 60% to nearly 500%. The greatest intensity of application is shown by the Netherlands with a consumption of 90 kg. of nitrogen per hectare of arable land, compared with 40 kg. in Germany, 24.5 kg. in the United Kingdom, 16 kg. in France and Italy and 9.5 kg. in Spain.

Ammonium nitrate is now established as the principal type of nitrogen fertilizer used in Western Europe and is followed by ammonium sulphate. Substantial quantities of these materials are used in the form of calcium ammonium nitrate and ammonium sulphate

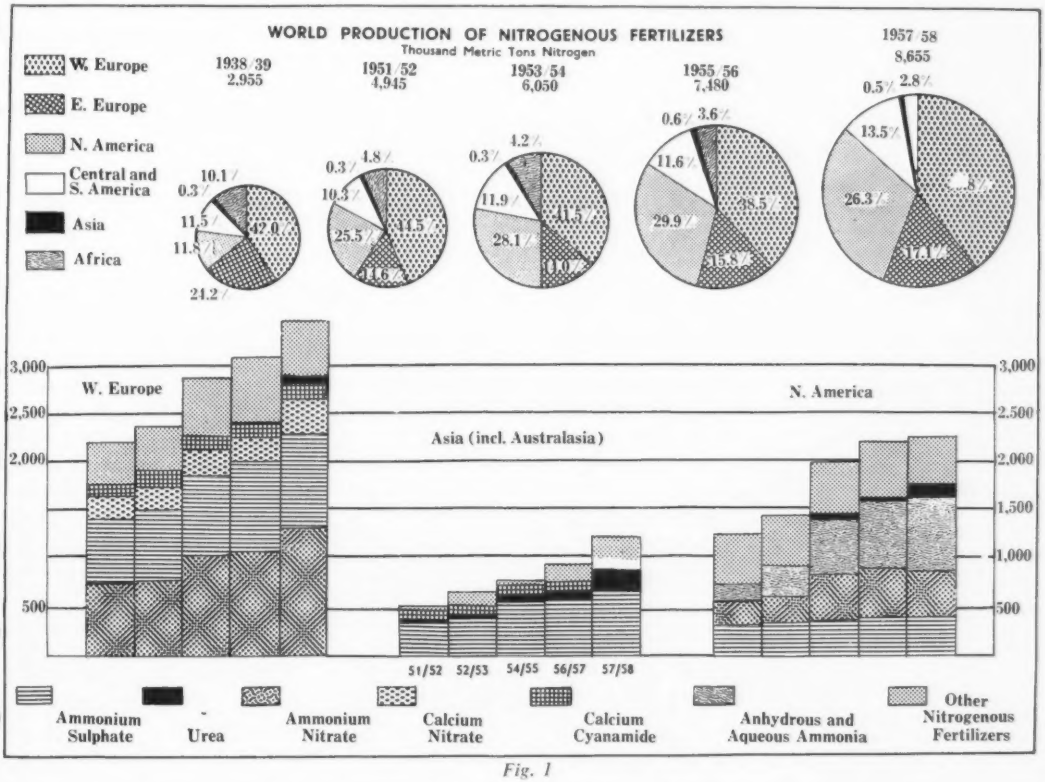


Fig. 1

compared with the pre-war period, has been shown by the United Kingdom with British farmers using over five times as much nitrogen as in 1939. In Italy, the use of nitrogenous fertilizers has doubled since 1939 and consumption has now reached a level of 280,000 tons a year, and in other countries nitrate. Consumption of ammonium sulphate has risen by 45% since 1952, whereas that of ammonium nitrate has doubled. These two fertilizer materials now account for 25% and 40% of Western Europe's total consumption. Calcium nitrate used principally in Denmark, Italy and Sweden accounts for 11% with

calcium cyanamide, the bulk of its consumption confined to Western Germany, now representing less than 6% of the total.

North America

Although the consumption of nitrogen, 13 kg. per hectare of arable land, is lower in North America than in Western Europe it has risen considerably in this respect since the 1930's, when the largest part was applied to crops such as cotton, tobacco, potatoes, fruit and vegetables, with grain crops receiving comparatively little.

Military requirements during the war, and the need for a greatly increased food production boosted consumption which, until 1952/1953, was further stimulated by the unusually high world-wide demand for food in the post-war years, a demand which resulted in fairly high prices for agricultural products on the world market. American agriculture, already greatly expanded during the war years, was assisted in meeting much of this demand by using increasing quantities of nitrogen, a development which was stimulated by a number of contributory factors. During the war the livestock population in North America was reduced and more synthetic nitrogen was needed to replace the loss of organic fertilizers. Even greater influence was exerted by the steep rise of farm revenue which, since 1939, has been more rapid than the rise in fertilizer prices. When in recent years this factor no longer applied, the Government's agricultural policy provided the new stimulus in that it advocated reductions in the area under cultivation for soil preservation (soil bank) resulting in farmers aiming for higher yields from smaller areas, binding them to a greater use of fertilizers.

The regional consumption of nitrogenous fertilizers has changed considerably within the last 30 years. In 1925 the bulk of consumption was confined to the Eastern seaboard states and to a lesser extent to the area South of the Great Lakes. During the 1940's it began to spread Westwards and this movement is continuing. The increase in consumption in the Western States has been much more marked than in the Eastern States because of the greater us of nitrogen on grain crops, and a general improvement in agricultural prices, which has led to increased application of nitrogen to pasture land. Prices have also been largely responsible for the nutrient ratio movement in favour of nitrogen as the adoption of relatively cheap fertilizers such as anhydrous ammonia and nitrogen solutions have resulted in a greater use of nitrogen. The use of anhydrous and aqueous ammonia for direct application is growing fast and is largely due to improvements in agricultural machinery. The consumption of urea is also growing rapidly in North America, both as a fertilizer material and as an animal feed, for which some 70,000 tons are used a year. In 1957/1958 consumption of urea in agriculture was at a level of 150,000 tons N.

Canada, although an important producer of grain crops, uses as yet relatively small quantities of chemical fertilizers, and her annual consumption does not exceed 50,000 tons of nitrogen.

Asia

In many parts of the world where consumption had been relatively low, prior to World War II, it has since increased rapidly with the planned advancement of agricultural production. This has been instigated by governments alone, or by governments working in co-operation with and with the help of international organisations such as the Food and Agricultural Organisation of the United Nations and the International Co-operation Administration, which have promoted the advisory work of technicians and scientists designed to disseminate the knowledge and technique of fertilizer application. In Asia, where remarkable increases in nitrogenous fertilizer consumption have taken place since 1950, services to give agricultural instruction and to promote the demand for fertilizers have been set up in several countries, including India and China.

Rice. Asia's main consumer of fertilizer.

The intensity of fertilizer consumption varies greatly between the countries of Asia. In 1955/1956 fertilizer consumption per hectare of arable land in Japan, China and India was :

Japan	...	...	...	109.6 Kg.
China	...	...	...	2.3 Kg.
India	...	...	...	1.0 Kg.

Taiwan, South Korea, Israel, Egypt and the Lebanon all have high rates of usage, comparable with those of Western European countries. Japan has the highest consumption of nitrogenous fertilizers in Asia, over 67% being in the form of ammonium sulphate. Ammonium nitrate and ammonium phosphate are rapidly gaining ground. Urea and ammonium chloride are also used in considerable quantities, in 1957/58 at a rate of 106,000 tons and 25,000 tons N respectively.

In China, which has probably the greatest potential demand in the world, 24% of the agricultural land lacks potassium, 55% needs phosphoric acid, while 96% lacks nitrogen. For thousands of years great use has been made of organic fertilizers, but it is only since the Communists came to power that the increased use of chemical fertilizers has become a major factor in the country's economic policy. Over 90% of the peasant population, some 125 million families, are now formed into agricultural co-operatives and receive energetic encouragement by the Government to extend their use of chemical fertilizers. Soil research stations have been established and widespread instruction in fertilizer application has stimulated consumption. Distribution of chemical fertilizers which are in very short supply is carried out under the auspices of the "All-China Federation of Marketing and Supply Co-operation." Although more organic than chemical material is still used, consumption of chemical nitrogen has been expanded by nearly five-fold since 1951 and is now at a level of some 390,000 tons N a year, of which 75% is in the form of ammonium sulphate.

India, like China, is faced with the problem of feeding a swiftly rising population (India's population is now increasing at the rate of 4.6 million annually) and much importance is attached to extending the use of chemical fertilizers. In all parts of India the soil is greatly deficient in nitrogen and although some 800,000 tons N are added in the form of organic materials, the untapped reserves of organic material are far greater than the amount used on account of widespread prejudice among large sections of rural population, a factor which makes the use of synthetic nitrogen all the more important. The Government is striving to increase fertilizer consumption and to spread knowledge of fertilizer technique, and the current Five-Year Plan makes extensive provision for this. India's current consumption of synthetic nitrogen fertilizers is at a level of 200,000 tons of nitrogen a year, of which 40% is in the form of domestic ammonium sulphate.

Eastern Europe

The Communist countries of Eastern Europe form with the U.S.S.R. a self-contained bloc where the production and consumption of chemical fertilizers are directly affected by State control. The aim is to raise considerably the level of consumption and achieve self sufficiency at the same time. The quantity of nitrogen used in synthetic fertilizers in the Eastern bloc countries has increased by 100% since before the Second World War, but this increase would have been greater had it not been for lagging production and a reluctance to import from other countries.

There is an acute shortage of nitrogenous fertilizers throughout Eastern Europe, although this varies in intensity from place to place, and they are rationed in almost all countries of the Communist bloc. The use of nitrogen fertilizers is most highly developed in Eastern Germany where it is now at a level of 260,000 tons N a year.

In spite of considerable expansion in her production capacity, the supply of chemical fertilizers in the U.S.S.R. is still totally inadequate and although the consumption of nitrogen in synthetic materials has now reached a level of 800,000 tons a year, there is a serious shortage in most areas. Whereas the quantities of fertilizer nitrogen used in the other Communist countries are relatively small, totalling to-day only about 650,000 tons N, the planned rate of increase in nitrogen application is appreciably greater than that forecast for any other parts of the world.

Industrial Consumption

One-sixth of the total world consumption of nitrogen is used in industry for a wide range of purposes; having risen steadily during the last six years, world consumption of technical nitrogen stands at 1.5 million tons.

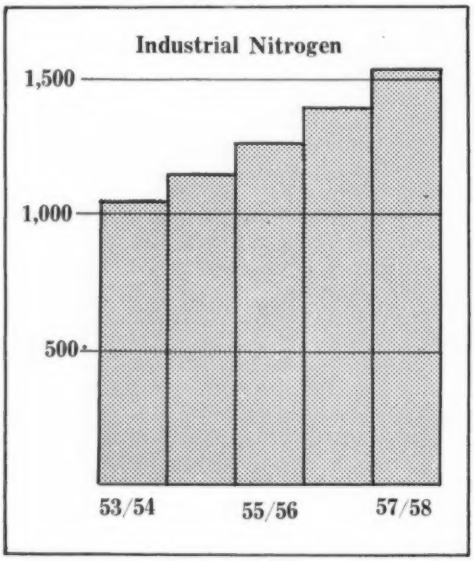


Fig. 2. Consumption of Industrial Nitrogen.

The use of technical nitrogen is considerably more developed in the United States than in any other country and annual consumption now exceeds 650,000 m. tons N. Western Europe, with a total of between 400,000 and 500,000 tons a year, ranks next after North America, both in total tonnage and on a per capita basis, while Eastern Europe has an annual consumption of about 200,000 tons N. With an annual consumption of 80,000 tons Japan shows a high rate of usage which is rising steadily.

Principal Industrial Uses of Nitrogen in the United States

	Metric Tons Nitrogen
Industrial explosives	125,000
Synthetic fibres	85,000
Plastics—resins	80,000
Paper manufacture	37,500
Metallurgy	25,000
Oil (refining)	25,000

The United States' lead has been achieved by better research facilities, improved manufacturing technique resulting in lower production costs, and more efficient methods of distribution. It is reasonable to assume that as other countries become more industrialised their consumption of technical nitrogen will develop on lines similar to that of the United States.

The principal nitrogenous materials used in industry are ammonia, nitric acid, ammonium nitrate and urea. Some 24% of the ammonia produced in the United States is used for industrial purposes.

U.S.A. Ammonia Consumed Directly or Indirectly in Industry

		%
Chemical products	8.5	(35.4)
Industrial explosives	5.0	(20.8)
Synthetic fibres	4.0	(16.7)
Paper pulp	1.5	(6.2)
Metallurgy	1.0	(4.2)
Oil (refining)	1.0	(4.2)
Miscellaneous	3.0	(12.5)
	24.0	(100.0)

The principal direct use of ammonia in industry is in the processing of paper pulp, where it is showing several process advantages over calcium sulphite, and demand now at between 25,000 and 45,000 tons a year, is likely to rise to a level of nearly 200,000 tons a year by 1970. Ammonia also has important uses in the oil industry, where it is used in the manufacture of catalysts and in neutralising the acid content of crude oil.

Nearly one-half of the nitric acid consumed in the United States is used in the manufacture of solid fertilizers and 27% in the manufacture of nitrogen solutions. Of the remaining 15% which is used in industry, explosives account for 10%, while another important use of nitric acid is in the treatment of metals and ores.

Ammonium nitrate is principally used in the manufacture of explosives and there is an important progressively increasing demand for it in open-cast mining. It is also used in the treatment of uranium ores, in the manufacture of fluid catalysts for oil refining and in the production of fine chemicals.

Urea is assuming an increasingly important rôle in industry, in particular in the

manufacture of plastics and of the 80,000 tons of technical urea used annually in the United States, about 70,000 tons are so consumed. Urea-formaldehyde resins are used for treating and dressing textiles and for treating and coating paper while urea is also used in the manufacture of adhesives, binders, moulding powders and protective coatings.

An important group of nitrogenous materials used in industry are the cyanides, melamine and cyanuric derivatives, which are used in the manufacture of plastics, solutions, textiles, resins, explosives, insecticides, fine chemicals and dyestuffs. Aliphatic amines are used in the manufacture of synthetic rubber, plasticisers, detergents, paints and ceramics, polishes and waxes, as oxidising agents and in the corrosion control of industrial fumes. They also have numerous potential uses in the cellulose industry.

Of the aniline and aniline derivatives consumed in the United States, 66% are used in the manufactuer of synthetic rubber, 17% in the production of dyestuffs, 10% in fine chemicals and 2% in the manufacture of photographic chemicals. Nitroparaffins are principally used as solvents, but they also have important potential rôles in the manufacture of polymers, explosives, insecticides, paints and pharmaceutical products.

In addition to being an important fertilizer material, sodium nitrate is consumed in the chemical industry as an oxidising agent in the manufacture of dyestuffs, ceramics and glass and in the production of other nitrates in metallurgy and in explosives, while acrylonitrile plays an important part in the manufacture of synthetic fibres, synthetic rubber, plastics, fibres, adhesives and solvents. The production of synthetic fibres in particular is expanding steadily throughout the world and nitrogen is extensively used in their manufacture, and in particular of acetate dacron, nylon, orlon and acrilan.

PRODUCTION

Ammonia synthesis, representing 81% of world nitrogen capacity and the principal method of production, continues to increase its share of the world capacity, and there are to-day some 350 synthesis plants in operation with a total capacity of some 8 million tons N.

World Nitrogen Capacity

Ammonia synthesis	81.0%
Calcium cyanamide	7.5%
By-product facilities	7.5%
Chilean nitrate	4.0%
	100.0%

The economics of ammonia manufacture have promoted the use of natural gas, fuel oil and refinery gases. Prior to the war over 90% of the world ammonia capacity was based on coal and coke, whereas the diversification of hydrocarbon materials since then is estimated to have changed the basis of world ammonia synthesis as follows :

Ammonia Synthesis Capacity

Natural gas	31%
Fuel oil	15%
Refinery gases	9%
Coal and coke	40%
Other	5%
	100%

Western Europe

The synthetic nitrogen industry in Western Europe has been favoured from the start by the availability of coal, steel, electric power, capital and technical skill, factors which have been largely responsible for Western Europe's position as the world's principal nitrogen producing area. Seriously affected by war damage, Western Europe's capacity has made a steady recovery since 1945 and has now reached an annual level of 4.5 million tons N, with production for all purposes at the annual rate of 4.0 million tons N.

Western Germany, whose production has doubled since 1951, is the leading producer of nitrogen in Western Europe and can claim some of the largest synthesis plants in the world, notably that of Badische Anilin and Soda Fabrik at Oppau. Although coal and coke are still the principal hydrocarbon materials used in the West German nitrogen industry, extensive plans have been made to use the very substantial reserves of natural gas that exist. Extensive use of natural gas is already made in Italy and France, where production is now at an annual level of 480,000

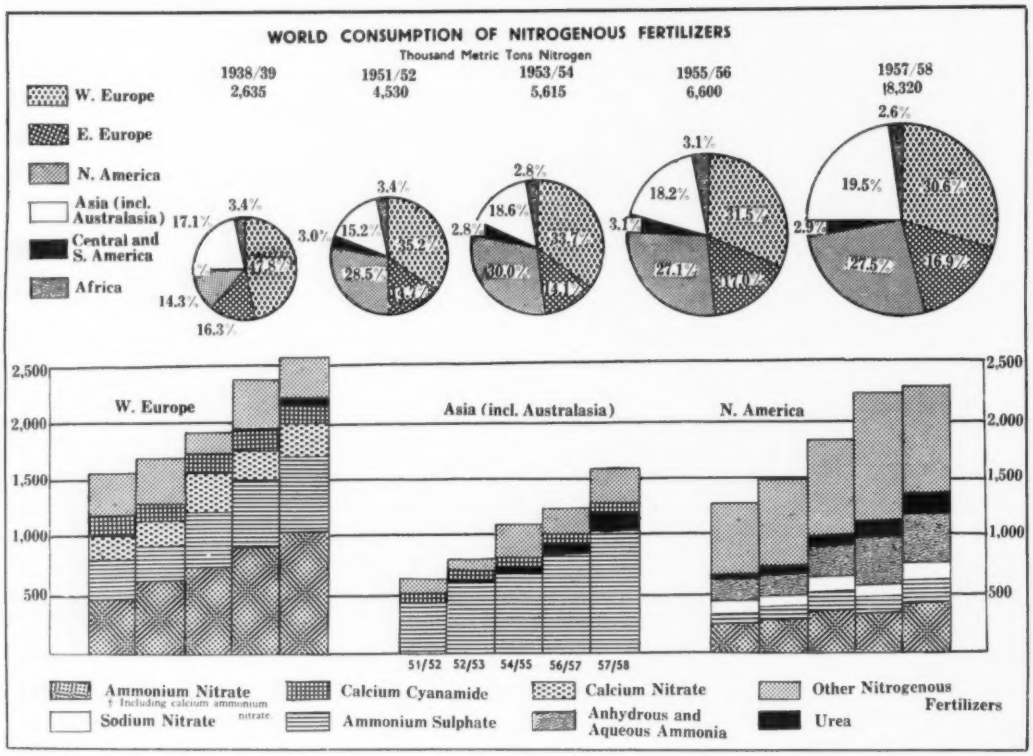


Fig. 3

and 550,000 tons N respectively. These two countries, with Western Germany, the Netherlands and Belgium, possess large and flexible centres of production, and it is significant that over three-quarters of Western Europe's capacity is situated within the area of the European Common Market. Important production facilities not located in the Common Market area are those of Imperial Chemical Industries, Norsk Hydro and Oesterreiche Stickstoffwerke at Linz.

Nitrogen Production in Western Europe 1957/1958

	%
Western Germany	30.7
France	14.8
Italy	12.3
Netherlands	11.0
United Kingdom	10.2
Belgium	7.5
Norway	6.6
Austria	4.5
Others	2.4
	100.0

North America

Although there has been a sensational rise in the consumption of nitrogen in North America since before the Second World War, there has been an even greater increase in production. Important extensions were made in capacity during the war to meet military demands, and the United States Army itself built 10 synthesis plants with a combined capacity of about 630,000 tons N per year. By 1945 the United States' capacity for all purposes was made up of :—

Annual Capacity

	Tons N
Pre-war private plants ...	34,500
By-product coke-oven capacity	170,000
New extensions	855,000
	1,370,000

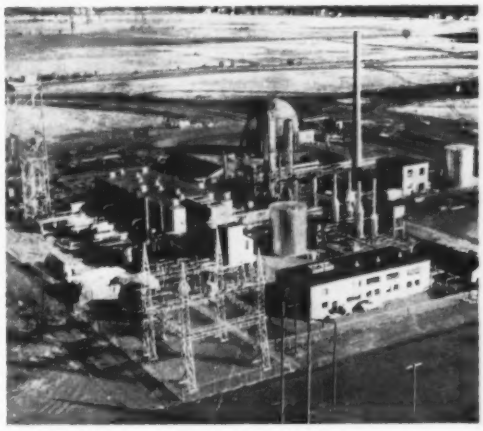
A second important phase in the expansion of nitrogen capacity in North America began in 1951 when the United States Government called for the erection, by 1957, of additional synthesis plants with a total capacity of 1.5 million tons N to meet agricultural and military demands. To encourage private firms to build nitrogen plants, the Government granted considerable taxation assistance in the form of very favourable depreciation allowances, and synthetic nitrogen capacity in the United States had increased to about 3,300,000 tons N by 1956. By 1957 this figure had risen to 3,550,000 tons, to which was added a further 230,000 tons in the form of by-product and organic material, so that between 1951 and 1957 production capacity in the United States rose by about 2.3 million tons N. Nearly half this capacity was erected with the benefit of major tax concessions.

Until 1954 production was maintained at a high percentage of capacity, but since then the proportion of the capacity utilised has fallen quite sharply. By 1956 only about 75% of production capacity was employed and it is now only about 60%, and even if several large plants, built during the war and now no longer in operation are omitted from the total capacity, the utilisation level would still not exceed 70%. By 1956 production capacity in the United States had expanded sufficiently to meet home consumption. Since then capacity has increased but, nevertheless, no ban on imports of nitrogen fertilizers has been imposed.

Before the Second World War, production facilities in North America were for the most part situated near coal deposits and hydro-electricity supplies as 90% of the nitrogen production was based on coke or coal. Since then the increasing use of natural gas and more recently of refinery gas and fuel oil as the source of hydrogen has changed the picture considerably. To-day, some 70% of the ammonia manufactured in North America is based on natural gas, about 10% on refinery gases and fuel oil and the remaining 20% on coke or coal. The use of oil refinery and natural gas allows greater freedom in choice of siting, and many of the nitrogen plants built since the war are situated in the West and South-West, whereas formerly production had been very largely centred in the Eastern States of the U.S.A.

Production of nitrogen in Canada of about 200,000 tons N only accounts for about 10% of the total for North America; it has increased rapidly during the last few years and is based largely on natural gas.

Several important differences exist between the production facilities in North America and those in Western Europe. The cost of raw materials for ammonia synthesis in North America is, on an average, only a quarter of that in Western Europe, and natural gas in North America is cheap enough to allow the widespread use of gas engines in nitrogen



General view of the $9 million ammonia plant of Canadian Industries Ltd., at Millhaven, Ontario.

plants, whereas the majority of auxiliary engines in Europe are electrically driven. Synthesis plants in North America have an average capacity of 200 tons N per day, whereas those in Western Europe have an average capacity of only about 100 tons N per day and are on the whole older, less standardised, more complex and designed for a high output per unit of energy consumed, with the result that maintenance is about 50% more expensive in Western Europe.

Asia

Production of nitrogen in Asia, which has risen by 230% since before the Second World War, is dominated by Japan, now accounting for some 80% of the total output. By 1950

Japan. General view of new urea plant of the Nihon Gas Co. at Niigata. Built by the Chemical Construction Co. the plant has a daily capacity of 90 metric tons.

Japanese production was able to meet her considerable domestic demand, and extensions to her capacity since then have been intended to provide for her growing export market in Asia.

Japanese producers have the necessary raw materials close at hand, but the internal price level has been such that their ability to compete in markets with Western European and North American producers has often been impaired. Vigorous efforts are, however, being made not only to extend capacity but to reorganise it on a more rational basis using less expensive methods of production, including the gasification of heavy oil and of low grade coal. Ammonium sulphate is still by far the most important nitrogenous fertilizer made in Japan, and production is entirely based on raw materials from domestic sources. Ammonium sulphate capacity is now about 720,000, tons N per annum, whereas production in 1957/1958 totalled 540,000 tons N.

The emphasis in the extensions to Japanese capacity is on the production of urea. Several ammonium sulphate manufacturers are turning to the production of this more versatile material. Urea capacity, which in 1950 totalled 8,600 tons N per annum, had risen to 135,000 tons N per annum by 1956 and now exceeds 250,000 tons N per annum. This considerable rise in the capacity and production of urea in Japan has been encouraged by a substantial domestic demand for both industrial and agricultural applications and by preferential taxation treatment for urea producers. Japanese producers can also see a fast growing market for urea in Asia. Other new plants have recently been erected for the manufacture of ammonium nitrate and ammonium phosphate, principally to meet demand from Japanese agriculture, which is turning increasingly to the use of these materials. Calcium cyanamide, formerly one of the more important nitrogen fertilizer materials made in Japan, it not being included in the current expansion plants as lack of domestic demand and the loss of some important export markets for this material, notably in South Korea, has led to insufficient use of capacity.

Japanese producers, handicapped in the past by shortages of electric power and by relatively high raw material costs are now overcoming many of their difficulties by improving the efficiency of their production facilities and are consolidating Japan's position as one of the most important producers of nitrogen, not only in Asia, but in the world.

Communist China has very ambitious plans to raise her production of nitrogenous fertilizers and the government is giving important priority to the fulfilment of the industry's objectives. Whilst it remains difficult to interpret correctly figures for capacity and production, impressive results have already been achieved. Production, which in 1951/1952 stood at 28,000 tons N has risen to 140,000 tons annually in 1957/1958.

Many of China's fertilizer factories are at present primitive and inefficient, but great efforts are being made to place production on a more rational basis and several older plants are being extended. Four large plants were under construction in 1958 and work is to start on 10 more this year. These new plants, when fully in operation, are intended to increase production by 365,000 tons N in the form of ammonium sulphate, ammonium

nitrate, ammonium chloride, ammonium bicarbonate and ammonium phosphate.

In India the State has played a very important part in promoting increases in capacity and production of nitrogen fertilizers and the second Five-Year Plan (1955/1956-1960/1961) places great emphasis on this. When four large government-owned plants are in full operation, India's present capacity of 100,000 tons N should reach 375,000 tons N and it is planned to raise capacity still further to a level of 381,000 tons N by 1960/1961, although the production target is much lower at 287,000 tons N as some of the new works will not by then be fully in operation. It is now government policy that private firms should be licensed to produce alongside State-owned plants, and it is expected that privately-owned capacity will amount to 24,000 tons N per year by 1961.

In addition to the important developments taking place in Japan, China and India, several other Asian countries, notably Taiwan, Egypt, and Pakistan, are energetically increasing their nitrogen production with the aim of achieving maximum independence of supplies from Western Europe and North America.

Eastern Europe

Even before the Second World War, Eastern Germany, Poland and Czechoslovakia had substantial nitrogen production capacities and the post-war period has seen the reconstruction of many pre-war plants. State control aims at synchronising production throughout the whole Eastern bloc area, coupled with ambitious plans to raise capacity in all countries. The total production of the Eastern bloc, now over 1.4 million tons N, has doubled since 1939, but the increase in production has varied considerably from country to country.

Production targets are seldom reached because they are often set too high for propaganda reasons and because there is frequently a failure to understand the problems associated with efficient plant operation. An example of this is that production targets are often too rigidly tied to anticipated supplies of raw materials. The production of nitrogen fertilizers in the Eastern bloc is not carried out on a sound commercial basis by Western standards and factories that make a loss, often because of unfavourable operating conditions, are subsidised by the State and the fertilizer industry as a whole receives large net subsidies as loss usually exceeds profit.

U.S.S.R.

Since 1928 there has been a vigorous campaign to extend fertilizer production in the U.S.S.R. and remarkable progress has been made since then. Many practical difficulties have had to be overcome, such as a shortage of skilled workers and transportation problems created by the vast distances. In the late 1920's there were only a few ammonium sulphate plants attached to coke ovens, whereas there are now more than 20 large synthesis plants in operation with a combined capacity of between 800,000 and 1 million tons N. The majority of these are situated near the coalfields in Western Russia, but it is planned to build more plants in Central and Eastern Russia and to base production increasingly on the use of natural gas. Of the nitrogen fertilizers, ammonium nitrate is produced in the greatest quantity and is followed by ammonium sulphate, while small amounts of calcium cyanamide, ammonium phosphate, urea, sodium nitrate and ammonium sulphate nitrate are also produced.

The current Five Year Plan (1956-1960) calls for an increase of 87% in the production of synthetic ammonia over the total for 1956 and 66% of this is to come from newly-erected plants. If this target is reached, production will rise to nearly 1.2 million tons N per annum. To minimise the high transport costs caused by the vast expanses of the U.S.S.R., particular emphasis is being placed on the manufacture of high analysis fertilizers such as urea and ammonium nitrate.

The production of nitrogen for industrial purposes is also being energetically developed. Its use is principally in connection with the manufacture of explosives, rocket propellants, synthetic fibres and metallurgy and in oil refining.

After the U.S.S.R., the most important producer within the Communist bloc is Eastern Germany. Nitrogen capacity, which in 1938 amounted to some 700,000 tons N annually, was reduced by war damage and the dismantling of plants for reparations to 230,000 tons

Bulgaria. General view of the "Stalin" nitrogenous fertilizer plant at Dimitrovgrad.

N. This capacity has now been raised to about 400,000 tons N, but there are not enough nitrate processing plants and the bulk of nitrogen fertilizer production is in the form of ammonium sulphate.

Like Eastern Germany, Poland's nitrogen capacity suffered heavily from war damage, but considerable efforts have been made within the framework of an inflexible economy to raise production, which now exceeds 210,000 tons a year. Ammonium sulphate is the principal nitrogen fertilizer manufactured and is followed by calcium cyanamide, calcium nitrate and ammonium nitrate.

Ammonium sulphate is also the most important nitrogen fertilizer produced in Czechoslovakia, where it is planned to make extensive use of natural gas from Southern Moravia for nitrogen synthesis. Three large nitrogen plants are in operation or under construction in Hungary, but expansion in this country has fallen short of the planned objectives. In Rumania and Bulgaria great efforts are being made to expand production, and several new plants are under construction. The great importance attached by the countries of Eastern Europe to expanding their production of nitrogen is but an example of a trend which is gaining strength throughout the world.

TRADE

The world trade in nitrogen fertilizers has been steadily increasing in volume since 1945 and is marked by the efforts of Japanese and United States exporters to secure markets for their surplus production in the face of intense competition from Western Europe.

Since 1945 the United States has changed from a net importer of nitrogen to a net exporter although at the same time certain foreign materials, notably Canadian calcium cyanamide and Chilean sodium nitrate have retained their position in the United States' market. The natural outlets for surplus production in North America are the markets of Central and South America, but demand here has risen very slowly, with the result that the bulk of North American exports are shipped to Asia. The greater part of these deliveries, now totalling some 100,000 tons N a year, are made under foreign aid programmes.

Asia

The large increase in Asian imports of nitrogen fertilizers cannot solely be attributed to the influence of foreign aid programmes as these has been a big rise in demand in countries such as China which are outside the scope of such programmes. Asian imports of nitrogen from the rest of the world have risen by 445% since 1953/1954 and are now at an annual level of 600,000 tons N and have undoubtedly done much to prevent a serious surplus on the world market. Japan has taken advantage of the growing demand in Asia to expand her exports which have increased four-fold since 1953/1954 and are now at an annual level of nearly 400,000 tons N.

	1953/1954 %	*1957/1958* %
Total Asian Consumption	100	100
Japanese Consumption ...	57	36
Asian Production (excluding Japan) ...	19	12
Asian Imports from Europe & N. America	13	32
Japan	11	20

Western Europe

Her position as the leading exporter of nitrogen has been due to Western Europe's lead in establishing a large and flexible production capacity well suited to meet the varying demands on the world market. Her exports have also been helped by deliveries made for international aid organizations. In 1938 Western Europe exported 345,000 tons N accounting for 42% of the total world trade. Seriously reduced by the war, this level was regained by 1950 and has risen substantially since then.

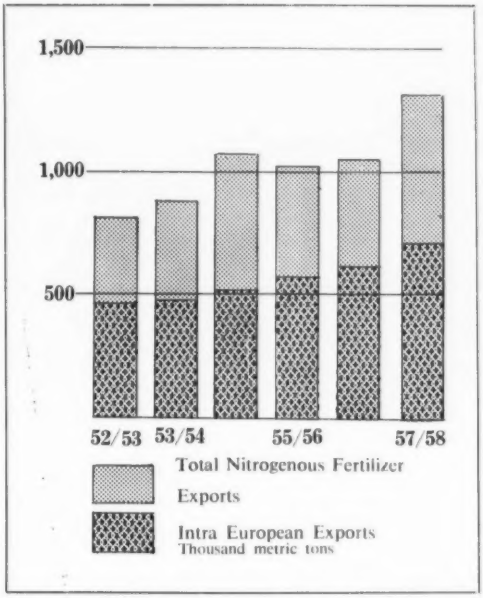


Fig. 4. Total West European Exports of Nitrogenous Fertilizers, showing the volume of Intra-European trade and net exports.

The participation of different countries in Western Europe's exports of nitrogen has varied considerably within the last few years :—

Of Western Europe's total exports of nitrogen fertilizers, nearly half go to markets within Western Europe itself, about 25% go to the Far East and 15% to Africa.

In general the increasing competition in the world markets from North America and Japan has resulted in the profit margins of Western European producers narrowing alarmingly. Exports of nitrogen from Western Europe to the United States have receded fast since 1954 and her markets in Central and South America are also being threatened by North American supplies. The closure of the Suez Canal in 1956 and 1957 harmed Western Europe's trade with the Far East where her exports are now facing growing competition.

United States

Before World War II the United States imported 190,000 tons N, one-half her consumption of nitrogen fertilizers. Imports rose in the immediate post-war years but have since receded to their present level of 300,000 tons N as production in the United States has caught and exceeded consumption.

A large proportion of the United States'

% of Total Exports of Nitrogen Fertilizers from Western Europe

	1951/1952	1952/1953	1953/1954	1954/1955	1955/1956	1956/1957	1957/1958
Western Germany ...	16.7	25.2	21.7	26.1	25.8	34.7	33.3
Belgium	18.3	12.2	15.9	15.0	15.3	12.0	14.8
Norway	18.9	16.1	16.5	16.8	14.3	15.4	13.0
Netherlands	11.9	13.1	13.7	11.8	14.0	15.2	13.8
Austria	9.1	8.7	10.0	7.5	9.0	10.0	7.8
Italy	4.6	4.8	5.8	6.2	8.9	10.0	10.0
United Kingdom ...	11.2	12.1	7.3	6.7	2.6	0.7	4.7
Other countries ...	9.3	7.8	9.1	9.9	10.1	2.0	2.6
	100	100	100	100	100	100	100

The fall in United Kingdom exports in 1956/1957, both relative and absolute, has been due to rising home consumption which has absorbed much of the surplus production :—

exports of nitrogen fertilizers are directed to South Korea, Formosa and India and are to meet a demand which might not be fulfilled were it not for foreign aid programme

Proportion of exportable surpluses in nitrogen fertilizer production in principal exporting countries in Western Europe

	1951/1952	1952/1953	1953/1954	1954/1955	1955/1956	1956/1957	1957/1958
Norway	80.0	78.0	81.7	81.6	80.1	78.9	79.2
Austria	70.4	74.7	74.9	74.3	77.0	71.5	62.0
Belguim	64.6	60.5	59.8	64.2	66.5	62.6	57.7
Netherlands	39.6	42.1	46.8	44.9	47.5	42.7	50.1
Western Germany ...	28.3	33.5	32.1	39.9	38.2	41.1	49.1
Italy	15.1	20.7	23.4	26.2	31.4	26.8	35.3
United Kingdom ...	37.4	25.7	23.2	18.8	9.9	6.9	12.9

deliveries. They are also meeting increasing competition from Japanese producers in these areas.

Japanese exports, which in 1955/1956 totalled 124,000 tons N, rose to 391,200 tons N in 1957/1958, and Japan is energetically improving her methods of production with the object of consolidating and expanding her position in the Asian market.

CONCLUSION

The salient feature emerging from this broad review of world nitrogen production, consumption and trade is the industry's spectacular growth which has trebled its level of operations in only two decades. No less important are the implications of expansion and the variety of complex problems resulting from the pressure of rising capacity, fulfilment of fertilizer needs and the exigencies of world-wide trading.

World consumption of nitrogen, at present divided between agricultural and technical uses in a ratio of about 5 : 1, holds immense scope for expansion. To-day, 83% of the world fertilizer production is applied to only 38% of the world agricultural land but as by far the greater potential demand for fertilizer nitrogen originates in the world's under-developed countries, lack of knowledge of fertilizer application is as much a handicap in promoting expansion as the inadequacy of financial resources. Political considerations have in recent years gone a long way towards overcoming the latter but, in the long term, fostering fertilizer techniques is likely to provide the stronger stimulus. Whereas the bulk of nitrogen usage will remain centred in fertilizers, technical applications, which in fields such as plastics, synthetic fibres and high energy fuels have already made great strides, hold promise of rapidly increasing in importance and scope. The extent of expansion will be largely governed by the producers' ability to supply the requisite technical nitrogen at an economic cost.

The greatest prospect for nitrogen use and expansion is, however, in the population pressure of China and India. Efforts to meet this from indigenous resources are particularly in evidence in China, but in the foreseeable future it will be the highly organised major producers of Western Europe and North America who will be called on to meet much of this demand.

International trade in nitrogenous materials has increased by 75% since 1953, and although the rate of progress is less than that of production or consumption, the impact of nitrogen commerce on the industry remains unimpaired. Under conditions of greater competition new features in the formulation of complex materials, in packaging, in transportation and in other aspects of commerce have emerged and are gaining influence. Probably the outstanding development in international fertilizer trading is the establishment of major merchant houses as focal centres of supply. Irrespective of national or company origin of materials, their flexibility of organisation has proved effective under the various competitive aspects of transportation, finance, government-sponsored deliveries and other features of present-day nitrogen commerce.

The evident excess of production capacity throughout the Western world has given rise to anxiety in some quarters but its main effect has been to promote usage wherever possible. This is in contrast with the nitrogen situation in Communist countries where the present inadequacy of production facilities is heightened by the ambitious level of planned fertilizer application and production growth. As this is progressively realised, these countries acquire the ability to divert output to Western markets if only for political ends.

These features present a picture of intensifying competition. The more far-reaching and effective answer has been and is increasingly becoming the improvement in production techniques be it the diversification of raw materials or advances in design of plant and equipment promoting the economic manufacture of a widening range of nitrogen material. As a corollary the cost of nitrogen is likely to fall, although this should only be looked upon as the means towards promoting the most rapid and widespread increase of nitrogen usage.

Supply · Trade · Prices

WORLD SUPPLIES of nitrogen have in recent months exerted increasing pressure on markets. This is partly attributable to producers anticipating, at the close of 1958, commitments which did not come up to expectations notably in the way of I.C.A. procurements. Particularly in Western Europe the level of stocks, which hitherto has not been excessive, appears to be rising and in consequence the market which is currently very sensitive has weakened. Urea and ammonium nitrate — particularly low-grade material — which represented the bulk of stocks at the close of last fertilizer year, are still in evidence and lately ammonium sulphate availability has also become excessive. Overall in Western Europe the expansion phase of plant capacity continues unabated. Of particular interest are developments in Italy where new capacity of 150,000 tons fertilizer nitrogen arises as co-product with synthetic rubber at the State-owned ENI plant at Ravenna. Now some 70% of domestic nitrogen fertilizer demand appears to be supplied from this source forcing a greater proportion of established output of Soc. Montecatini on to export markets.

In the **United States** the level of production, after last summer's decline, has risen to that prevailing one year ago, but the supply position still appears almost in equilibrium. Expansion of plant capacity, although slower, is still significant notably in terms of anhydrous ammonia and urea, the latter, having added 172,700 tons since the beginning of 1958, is due to reach 920,000 tons per annum capacity by the end of this year. Current United States ammonium sulphate stocks are low, those of ammonium nitrate and urea are substantial, whilst anhydrous ammonia is in excessive supply. The start of the domestic fertilizer season has nevertheless given markets an optimistic tone.

In **Japan** the serious situation resulting from the continued boycott by Communist China of fertilizer imports coupled with a decline in home sales has resulted in drastic steps being taken by the government and the Ammonium Sulphate Export Corporation. Hitherto the Corporation purchased from producers only such quantities as had already been sold by individual exporters. Now the Corporation is to purchase the entire tonnage allocated to export. In the year 1st August 1958-31st July 1959 this amounts to 1.16 million tons, of which about 200,000 tons is expected to remain unsold especially as only 800,000 tons have so far been sold. To discourage further price cutting the export company will be allowed to buy from a manufacturer whenever his stocks exceed a level to be determined by the Association. To support these operations funds are to be provided under joint guarantees by Association members. The gravity of the situation is underlined by the measures introduced by the Ministry of International Trade and Industry which plans to rationalise the industry over five years from 1959 at a cost of U.S. $90 million. In so doing the notional production cost of ammonium sulphate is to be decreased by U.S. $7 to $47 per metric ton. Despite the intended closure of inefficient plants, production at the end of five years is to be 1.1 million tons nitrogen against 0.9 million tons at present, whereas exports are to be 460,000 tons N (391,000 tons in 1957/58). The main feature of this development is the change in basing ammonia synthesis on oil, natural and refinery gas instead of coal. In addition to plant expansion and new construction, emphasis on urea and ammonium chloride and high analysis fertilizers, which have a lower unit cost of production, is encouraged. Already urea production at 550,000 metric tons represents over one-quarter of total Japanese nitrogen production which, if the current fertilizer target is realised, stands 87% higher than five years ago.

The recent purchase by **India** from Japan of 137,000 tons ammonium sulphate and 40,000 tons urea, brings her imports during the current fertilizer year to about 70,000 tons nitrogen, but although this represents an

increase over the corresponding position in 1957/58, the gap between the planned level of nitrogen use—now 350,000 tons N—has in fact widened.

In the **Far East,** although two urea plants, one in Taiwan on the point of starting operation and the other in South Korea due later this year, are about to augment indigenous supplies, there are no signs of lessening import demand, much of it to be fulfilled with the aid of I.C.A. funds. Imports to this area this year are expected to total about 200,000 tons, the bulk of which may be expected to originate in Japan. Communist China is expected to seek at least 250,000 tons nitrogen from European suppliers.

Australia, as the result of increased activities at Risdon, now produces in excess of domestic needs and it is estimated that an export surplus of about 15,000 tons ammonium sulphate remains which, although negligible in relation to the large consumption of the Far East, is nevertheless adding to the world surplus.

Throughout the nitrogen industry emphasis currently centres on urea, notwithstanding world-wide additions in plant capacity for products of lesser concentration or those in the United States which focus on anhydrous ammonia and nitrogen solutions. In addition to fertilizer and technical use, urea promises to find wide application as animal feed, of which there is already evidence in the U.S.A. In world export markets West German and Dutch urea for fertilizer and technical use is establishing a strong position on account of outstanding quality of colour and physical condition. Japanese urea exports are finding a ready market owing to the willingness to cut prices ; whereas the difficulties encountered by United Kingdom and United States material is mainly attributable to their reluctance to do likewise. Norway and Italy are active suppliers and Canada is expected to enter world markets with new production this spring.

Although nitrogen use during the current fertilizer year, based on indications to date, is not as great as had been expected, there is expansion in all major and in most other consuming countries so that the level of 9.8 million metric tons—last year's peak in world usage—will undoubtedly be exceeded. On a world-wide basis it is estimated that in order that employment of plant should not fall below the 1958 level, consumption in 1959 will have to rise by about 11% to take up the output of new plant coming on stream.

FREIGHT

Under the prevailing conditions of reduced prices the procurement of tonnage at favourable rates assumed added importance. Whereas the world-wide ocean freights markets remain weak as laid-up tramp tonnage nears 7 million GRT, there are isolated instances of shortages of vessels resulting in a temporary firmness of local freight rates.

An indication of current rates is as follows :—

To	*From*		
	Japan	*U.S.A.*	*W. Europe*
S. Korea (U.S. Liner)	$ 8.50	$10-$12	—
S. Korea (Tramp)	$ 2.75-$3.50	$ 8-$10	$ 8.50
India (Tramp)	$ 6.40	—	$ 7.30-$8.50
India (U.S. Tramp)	—	$14	—
China (Tramp)	—	—	$ 7.30-$8.50
Central America	—	$13	$ 4.50
South America Atlantic Ports	$15-$16	$ 6.75	—
South Africa	—	—	$ 5.50

PRICES

World prices of nitrogen materials have weakened in recent months. Satisfactory sales results in the early autumn of 1958 left European producers with a favourable stocks position and held promise of price stability and a firmer tone for the New Year. That it was not realised may be attributed primarily to the pressure of Japanese supplies which, failing for political reasons to find an outlet in Communist China, had to be sold elsewhere and the urgency of these transactions was reflected in the lower prices. It is symptomatic of the world market that even an isolated instance of a cheaper sale establishes a new price level. At the same time, although disposals from the Japanese export surplus appear to have directly contributed to the present price decline, the underlying cause is the prevailing increase of the gap between world plant capacity and actual production and sales.

DOMESTIC PRICES

Except for the United States, the majority of home markets of the major producers are virtually secure from outside competition and domestic prices tend to be substantially higher and are widely supported by fertilizer subsidies.

United States

On 1st January seasonal increases were posted applicable to the price of ammonium nitrate ($3), anhydrous ammonia ($4) and nitrogen solution ($6). Current price levels are :—

Coke-oven ammonium sulphate
$32 per short ton f.o.b. in bulk
Synthetic ammonium sulphate
$35 per short ton f.o.b. in bulk
Ammonium nitrate
$68 per short ton f.o.b. plant in bags
Ammonium nitrate
$57 per short ton f.o.b. plant in bulk

This last price applies also to Canadian material at point of shipment. Imported calcium ammonium nitrate at $44.50 f.o.b. rail cars at port of discharge competes with domestic lime ammonium nitrate. Anhydrous ammonia of fertilizer grade is quoted at $88 per short ton, in tanks, whereas refrigeration grade is $2.50 dearer. The promise of sale at $63 made by Best Fertilizer Company in California last autumn has made a profound impact not only on price outlook for the West Coast but also on construction programmes and the tenor of the U.S. market as a whole.

West Germany

According to official sources domestic prices of nitrogenous fertilizers during the fertlizer year 1957/58 were as follows :—

	D.M. per metric ton	*equivalent per metric ton product*	
	N	*$*	*£ s.*
Ammonium sulphate ...	1,135	56.70	20 6
Ammonium nitrate ...	1,165	92.96	33 4
Calcium nitrate ...	1,360	50.37	18 11
Chilean sodium nitrate	1,400	53.37	19 1
Calcium cyanamide (oil treated) ...	1,330	66.57	23 15

They represent an increase of 3-4% over those prevailing in the preceding year. Overall fertilizer subsidies in 1957/58 are expected to exceed substantially the budget of D.M. 260 million but no such latitude is said to be permissable in the provisions for the current year, which amount to D.M. 316 million.

United Kingdom

Current quotation of United Kingdom nitrogenous fertilizers delivered to the farmers nearest railway stations are :—

	per ton	*subsidy*
Ammonium sulphate (20.6% N) ...	£21 5s. 6d.	£9 18s. 0d.
Nitro chalk (15% N) ...	£18 10s. 0d.	£7 7s. 6d.
Nitra Shell (20.5% N) ...	£24 8s. 6d.	£9 14s. 9d.
Chilean nitrate of soda (16% N)	£27 0s. 0d.	£7 12s. 0d.

Nitra shell with 23% N quoted at £26 15s. (subsidy £10 18s. 6d.) and magnesium nitra shell at £27 8s. 6d. (subsidy £9 14s. 9d.) are reported to attract much interest.

Ammonium Sulphate

Last November f.o.b. quotations for the South Korean tender, which incorporated 521,500 tons ammonium sulphate, ranged upward from $41 per metric ton in 50 kgs. bags for supplies from Holland, Italy and Belgium, $41.85 from Japan, $42 from West Germany, $42.95 to $43.50 from Canada and $43.70 to $51.88 from the United States. A tender in India for 89,000 tons ammonium sulphate was also secured by Japanese suppliers at $41.85 per metric ton f.o.b. ($50.35 c. & f.). In both instances freight advantage told heavily in Japanese suppliers' favour. Current quotation of West European material, notably West German, Dutch and Belgian, indicates posted prices of $44 per metric ton f.o.b. in bags. This price level is subject to fluctuation of up to 15% and especially large buyers, such as Communist China, would currently be considering prices of about $38-$39 per metric ton, equivalent to a bulk price of about $5 per metric ton less.

Ammonium sulphate nitrate (26%N) continues to be promoted by Ruhr-Stickstoff A.G. on account of its agronomic rather than its economic advantage, although generally the unit price is comparable with this supplier's price for calcium ammonium nitrate. Whereas last December an increase of up to $2 had been expected, the weaker markets have caused current bulk prices to decline by as much as 10-12%.

Ammonium Nitrate

Japan was successful in securing part—5,000 tons—of last November's South Korea tender for this material (34.5% N) on the basis of U.S. $66.59 f.o.b. whereas United States suppliers obtained 18,000 tons of 33.5% N material with a c. & f. quotation of U.S. $71.01. Prilled material in the United States continues in ample supply. On European markets offers of ammonium nitrate from Eastern Europe have been noted in recent weeks at f.o.b. prices of about $70 for a material stated to have 34% N. West European supplies (33.5% N) are on offer at prices equivalent to $82-85 per metric ton f.o.b. packed in steel drums.

Calcium ammonium nitrate (20.5% N) of West European origin which was quoted successfully in the South Korean tender at $39 f.o.b. per metric ton has, according to recently reported f.o.b. quotations, remained at this price level. In consequence it appears at present a little more expensive than ammonium sulphate.

Calcium Cyanide

The sale to South Korea included 50,000 tons of 21.1% N material of Japanese origin at $49.40 per metric ton c. & f.

Urea

As the result of the significant excess of export supplies over current demand this market is in a considerable state of flux. November's tender sale to South Korea comprised 70,000 tons Japanese urea at $94.60 per metric ton f.o.b. ($103.10 c. & f.) and 26,200 tons U.S. material at prices ranging from $103,01 to $110.19 per metric ton c.&f. India purchased from Japan at $107.30 per metric ton c. & f. Currently U.S. suppliers appear too expensive compared with Japanese exports, ranging from $95-105 per metric ton f.o.b. or $90-100 per metric ton by West European, notably Italian, German and Dutch suppliers.

Chilean Sodium Nitrate

As the U.S.A. is the principal outlet for Chilean sodium nitrate the price reduction of $5.25 per short ton in United States on 1st October 1958 has embarrassed all but the large mechanised producers. The new price is $44.50 per short ton.

Summary

The continued expansion of plant capacity at a time of reducing prices may appear anomalous but is justified by those concerned in the light of medium and long-term developments. This applies particularly to large chemical and petrochemical enterprises with great financial strength who are determined to have capacity in regular operation when demand, and with it prices, start rising. Much expansion of capacity which is evident, notably in Western Europe and Japan, is effected to improve efficiency and thereby competitive strength of old plant which no longer permits economic operation at prevailing low prices. The adjustment of production rates and the flexibility in the employment of plant capacities indicates the determination on the part of the major producers to sustain the strength of industry, under the prevailing competitive market conditions.

THE FAUSER-MONTECATINI UREA PROCESS

DEVELOPED BY SOCIETA MONTECATINI OF MILAN, a total liquid carbamate recycle process is now available to the chemical industry. Arrangements for engineering and constructing an urea plant in the U.S.A., U.K. and several other countries using this process can be made through The M. W. Kellogg Company of New York and Kellogg International Corporation of London. Intended for the production of high-purity urea of exceptionally low biuret content and providing conversions approaching 100%, the new process substantially reduces investment for compression facilities and eliminates several operating and maintenance problems associated with other urea processes.

Società Montecatini have twenty-three years' experience in the development of urea processes and in the production of urea for agriculture and industry. Some twenty-nine plants of Montecatini design are in operation or under construction in eleven countries and The M. W. Kellogg Company has added its experience in chemical engineering and processing to provide the full operating conveniences afforded by American chemical engineering practice.

An important feature of the new process is the use of a pumped carbamate recycle stream. By this means, a large proportion of the unreacted ammonia and carbon dioxide in the reactor effluent is recycled to the reactor as an aqueous solution of ammonium carbamate. This development represents a substantial improvement over previous practice in which it was necessary for all of the unreacted ammonium and carbon dioxide to be separated and re-compressed. Operating and initial investment costs are substantially reduced for that portion of the recycle which is carried out as a liquid solution rather than as vapour.

Several Montecatini process arrangements are available incorporating the liquid recycle feature, and each arrangement uses the basic Montecatini reaction for production of urea. Ammonia and carbon dioxide are compressed into a reactor where, under conditions of controlled temperature and pressure, they react to form a mixture of urea and water, ammonium carbamate and ammonia. The reactor is water-cooled to maintain low metal temperatures and to remove the heat of the reaction. Under certain conditions, where commercially desirable, the reactors can be cooled with boiling water, thereby producing steam as a by-product. The exceptionally low biuret content of urea produced by the Montecatini process (less than 0.5% for urea solution on

MATERIAL BALANCES PER TON OF UREA

	Once-Through	*Partial Recycle*	*Total Recycle (Selective Separation and Liquid Phase)*
		Short tons	
Feed			
Ammonia	1.40	0.88	0.59
Carbon Dioxide ...	1.25	0.91	0.77
Nett Consumption			
Ammonia	0.59	0.59	0.59
Carbon Dioxide ...	0.77	0.77	0.77

UTILITIES

		Total Recycle				
	Once-Through	*Partial Recycle*	*Selective Separation*	*Liquid Phase*	*Conversion to Prills*	*Conversion to Crystals*
Electric, KWH/ton	170	130	170	110	30	30
Steam, lb/ton	2,300	3,800	5,800	4,600	700	700
Water, 85°F, gallons/ton ...	10,000	15,000	25,000	25,000	5,000	5,000
Fuel, BTU/ton of urea ...	—	—	—	—	—	600,000

Electric power where possible.

a water-free basis), is in part the result of low residence time and low metal temperatures maintained in the reaction process and in part is due to the use of a specially designed vacuum evaporator where biuret formation is kept to a minimum.

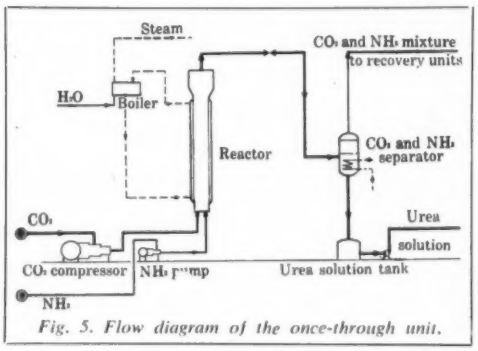


Fig. 5. Flow diagram of the once-through unit.

The four Montecatini urea processes are the once-through, partial recycle, total recycle with selective separation of residual gas and total recycle in liquid phase arrangements.

The Once-through Unit

In the once-through urea solution unit, the basic reactor effluent is throttled to a separator where ammonia and carbon dioxide gases are removed for recovery. Aqueous urea solution is delivered to a tank.

Partial Recycle

In the Montecatini unit using partial recycle, the basic reactor effluent is expanded in a heater where carbamate decomposes to ammonia and carbon dioxide. These gases are cooled, condensed by adding water, and then recycled to the reactor as a liquid carbamate solution. The balance of the original reaction production passes through a separator where ammonia and carbon dioxide gases are removed for recovery, the remaining aqueous urea solution being delivered to a storage tank.

Total Recycle with selective separation of residual gas

This process recovers three-quarters of the unreacted ammonia and carbon dioxide from the basic reaction effluent and recycles this recovery product as a liquid ammonium carbamate solution. Additional ammonia and carbon dioxide are recovered and used as feed. The basic reaction effluent is expanded in a heater where the carbamate is broken down to ammonia and carbon dioxide gases which are cooled, condensed and recycled to the

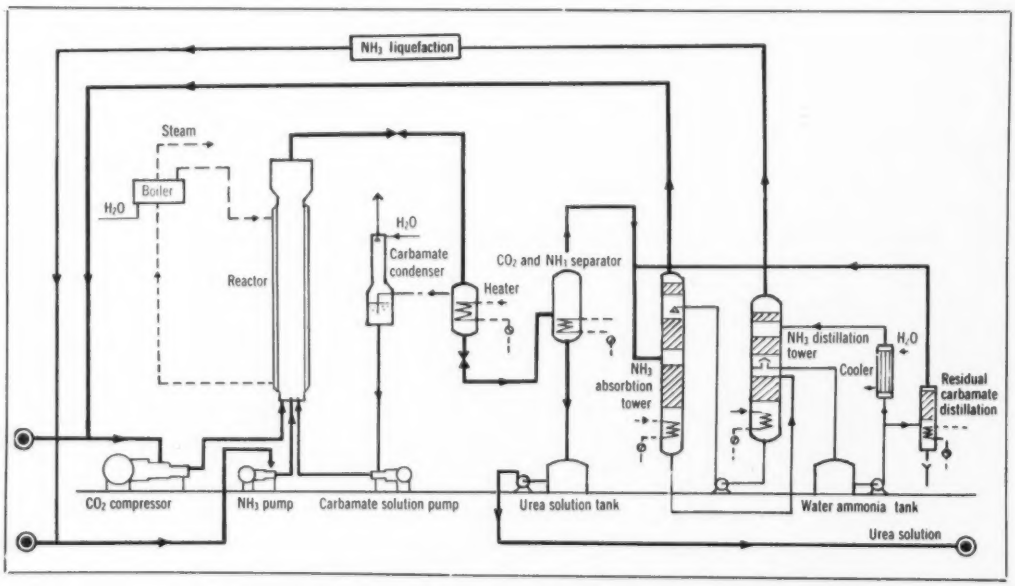


Fig. 6. Flow diagram of total recycle with selective separation of residual gas.

reactor as the liquid carbamate solution. The remainder of the original reactor effluent passes through a separator where ammonia and carbon dioxide gases are removed for recovery. Aqueous urea solution is delivered to storage. In the recovery section the mixture of ammonia and carbon dioxide are separated in a simple two-tower system; ammonia is absorbed in an aqueous selective solution in an absorption tower and removed in a stripping tower. The ammonia and carbon dioxide gases are then returned to the main reactor feed streams.

equipment for selective separation of residual gases, the liquid phase recycle arrangement affords considerably greater simplicity of operation coupled with lower operating costs.

Corrosion Problems Overcome

Mild and carefully controlled reactor conditions are used in the new process to eliminate corrosion, a major problem in urea plants. By careful selection of composition and temperature in the reactor, it has been possible to use commercially available stainless steel for the reactor lining and other surfaces

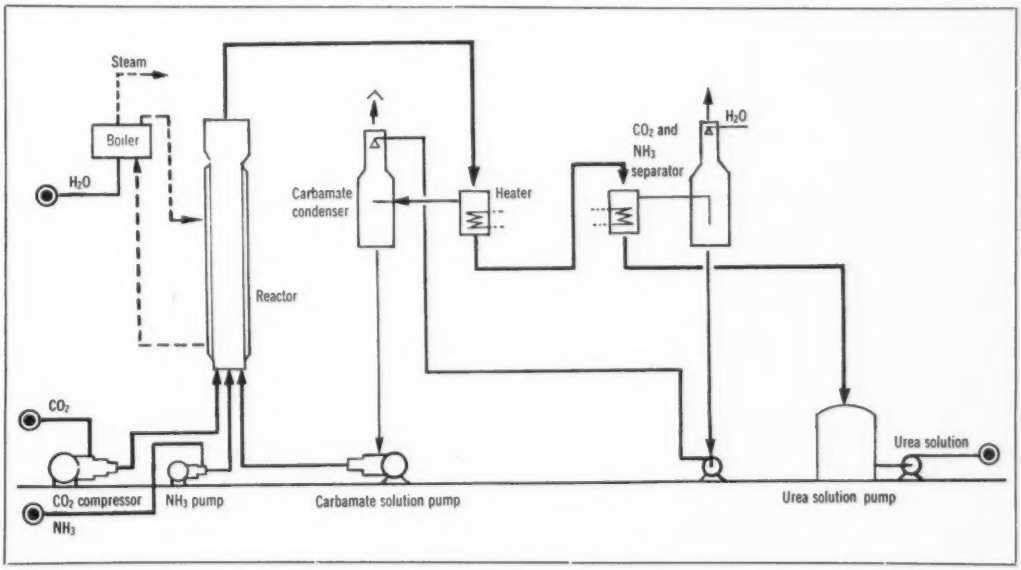


Fig. 7. Flow diagram of total recycle in liquid phase.

Total Recycle in liquid phase

In this, the most up-to-date arrangement, the residual gases, separated under low pressure from the solution after the first recycle, are also recycled as a liquid solution to the reactor. This is carried out by means of a second recycle section where gases separated from the solution and condensed are recycled to the first condenser. This liquid phase recycle allows reduction in power and steam consumption as well as in the investment cost in comparison with the residual gas selective separation arrangement. Although slightly less efficient, by eliminating the use of

exposed to corrosion with excellent results. No silver or lead is required and initial reactor fabrication has been simplified to ensure extended trouble-free operation. The use of specially designed piping and wash-out systems overcomes the problems of corrosion and plugging generally encountered in urea plants.

Crystals

Urea solutions produced by any of the arrangements of the Montecatini process may be readily converted to crystals or prills for agricultural or industrial application. Urea crystals are produced by feeding the urea solution through a filter into a crystaliser. The

crystal slurry from the crystaliser is centrifuged and is fed into a dryer to remove moisture, the mother liquor being returned to the feed stream. After drying and eventual cooling, the urea crystals may be bagged for shipment. The moisture content of urea crystals produced by the Montecatini process is about 0.2%.

Product Quality Crystals	*Maximum*
pH (10% solu. at 20°C) ...	9.7
Moisture	0.4%
Ash	15 ppm
Liquid ammonia	35 ppm
Biuret	0.5%
Iron	3 ppm
Colour	10 APHA
Turbidity	10 APHA

Prills

Especially suitable for spreading by agricultural mechanical equipment, high density, air-free urea prills are made by spraying molten urea into a prill tower, an inexpensive box-like structure ; the resulting drops of liquid, falling through a rising column of air, are cooled and solidified. The hard, free-flowing urea prills are discharged from the bottom of the tower into a cooler. They are then ready for bagging or storing.

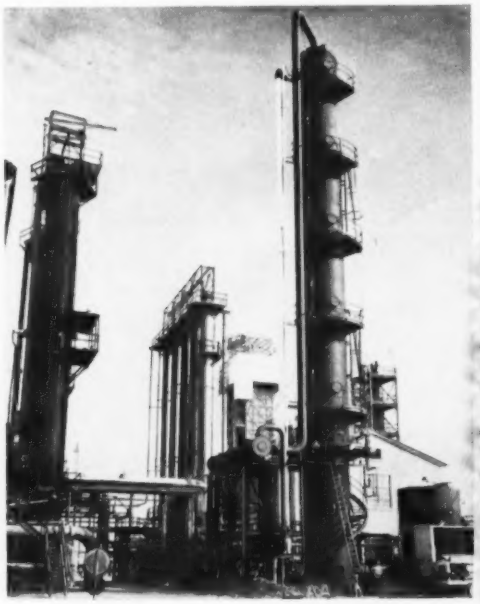
The size of the prills is controlled by conditions at the prill tower spray headers, and range from 1.0 to 2.5 mm. for 95% of the product. Hardness and low moisture content ensure free-flowing prills. The residual moisture of prilled urea made by the Montecatini process is below 0.6%, this low moisture content being achieved without a prill dryer by means of a specially designed evaporator. Where desired, a dryer can be used to reduce moisture to 0.2%.

Product Quality Prills			
Biuret	0.8%	Prill Size	1.0 to 2.5 mm.
Moisture	0.6%	Hardness	500 grams.

High Purity and Low Biuret Content

The urea produced by this process is exceptionally pure, free from oils and metals and, even in the prilled form, is white, an important quality as off-white material is considered to have impurities. Colour in urea is generally due to the presence of metallic compounds resulting from corrosion.

Biuret, a condensation product of urea, withers the leaves of some plants and minimum biuret content is the most important single property of urea produced for agricultural use. The biuret content of urea produced by the Montecatini process is less than 0.8% for prills, below 0.6% for crystals and less than 0.5% for urea solution on a water-free basis, well under the levels of 2.5 and 3% considered hazardous to plant life.



Urea plant of the Spencer Chemical Co. at Henderson, Kentucky, which employs partial recycle in liquid phase. Left foreground, hot carbonate absorber; right foreground, hot carbonate regenerator; and background, copper liquid absorbers, prilling tower and reactor.

Conclusion

The Montecatini process appeals to many urea producers as it affords low initial cost, low maintenance and operating costs and produces high-purity urea of exceptionally low biuret content. Perhaps the most important feature of the process is that it overcomes the great problem of corrosion normally encountered by operators of urea plant. The process is establishing itself and it is likely to establish itself in many new urea installations throughout the world.

THE TEXACO-CASALE AMMONIA PROCESS

The Foster Wheeler Sequence

ONE OF THE MOST SUCCESSFUL and widely applied methods for the manufacture of anhydrous ammonia is the Casale process used in conjunction with the Texaco partial oxidation process in the production of hydrogen. After World War II, Foster Wheeler Corporation of New York made an exhaustive study of existing processes for the production of synthetic ammonia from hydrocarbon material. Flexibility and economy of operation afforded by the Texaco and Casale processes led Foster Wheeler to select them as a basis for their design for a complete process plant to produce ammonia. Principal licencees for the Texaco process and sole licencees for the Casale process, Foster Wheeler Corporation, using the combination of the two processes, have built ten plants with a capacity totalling 1,750 tons of anhydrous ammonia per day.

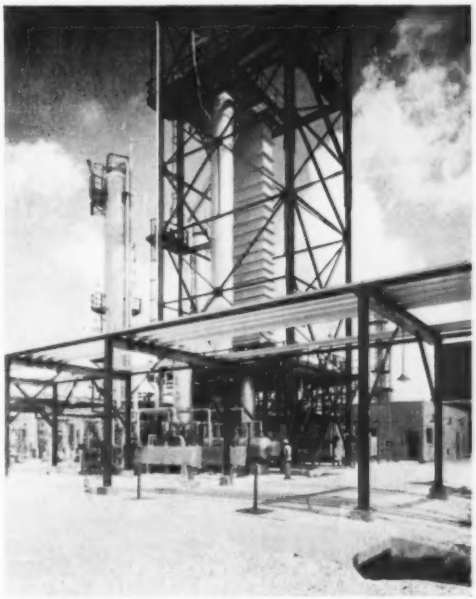
Description of Process

The manufacture of synthetic ammonia by the Foster Wheeler processing sequence involves six principal stages, each stage being a process unit complete in itself.

Air Fractionation: Air, after passing through filters and a caustic scrubber is compressed to approximately 600 p.s.i.g. It is then cooled and enters the air fractionation plant. There, by means of heat exchange with the effluent gases and a heat-removal expansion system, it is reduced in temperature and condensed to a liquid state and then fractionated into liquid oxygen and gaseous nitrogen.

Partial Oxidation: The liquid oxygen is pumped from the air fractionation plant at a pressure of about 400 p.s.i.g., passes through the heat exchange section, is further heated and meets the hydrocarbon feed gas at the synthesis gas generator. The nitrogen in vapour state passes through the air plant heat exchanger where it cools the incoming air and is moved by a compressor to the ammonia synthesis section. Part of this nitrogen stream, compressed to 300 p.s.i.g., re-enters the air fractionation plant, where it is liquified for use in the Liquid Nitrogen Wash system. The feed gas is compressed and heated and is then mixed with the pre-heated oxygen in the synthesis gas generator.

Raw hydrocarbon material fed to the Texaco generators can be natural gas or



Reactor cell of a Casale Ammonia Plant

practically any refinery gas, saturated or unsaturated and fuel oil feed may be substituted for gas with the minimum of plant modification. Non hydrocarbon contaminants, such as carbon dioxide, nitrogen, hydrogen sulphide or other sulphur-containing gases do not have any direct adverse process effects. The feed gas composition is flexible because the process does not employ an expensive catalyst which can be temporarily or permanently poisoned by sulphur or rendered inefficient by unsaturated hydrocarbons. The partial oxidation process uses a simple refractory-lined vessel instead of a complex furnace with expensive alloy tubes and a sensitive catalyst which are subject to deterioration and constant maintenance.

Operating at about 350 p.s.i.g., the process permits the fullest use of available feed gas pressure.

Shift Conversion: The products of the high-pressure oxidation, mainly carbon monoxide and hydrogen, are water quenched upon leaving the synthesis gas generation stage and then re-heated to predetermined temperatures before entering the shift converter, in the presence of a catalyst. The conversion of carbon monoxide to carbon dioxide is completed and additional hydrogen is obtained from the dissociation of the water molecule. Shift conversion of the generator product-gas with steam is conducted under pressure with a pressure catalyst in an established converter design. Pressure operation is advantageous thermodynamically and results in low concentration carbon monoxide in the exit gas. The latest designs require no outside steam if there is a supply of condensate available. The synthesis gas, on leaving the shift conversion unit, is passed through a heat exchanger and is then cooled to 100°F for carbon dioxide removal.

Carbon Dioxide Removal: In this system the gas is brought into contact with monoethanolamine which removes the carbon dioxide in order to produce an essentially pure hydrogen stream containing only a small percentage of impurities. The carbon dioxide is stripped from this absorption medium in a reboiler system which uses heat from the synthesis gas as it leaves the shift converter. There is no surplus heat from this operation.

Liquid Nitrogen Wash: The synthesis gas now freed of the bulk of its carbon dioxide passes through a caustic wash to remove residual carbon dioxide, is then dried, and, by way of heat exchange with effluent gases, enters the Liquid Nitrogen Wash system, where any unconverted methane, carbon monoxide and other gases of similar or higher boiling point are condensed through contact with the liquid nitrogen.

The use of liquid nitrogen scrubbing for removal of carbon monoxide, methane and argon produces a synthesis gas of exceptionally high purity, thus reducing to a minimum the amount of purge gas from the ammonia synthesis train.

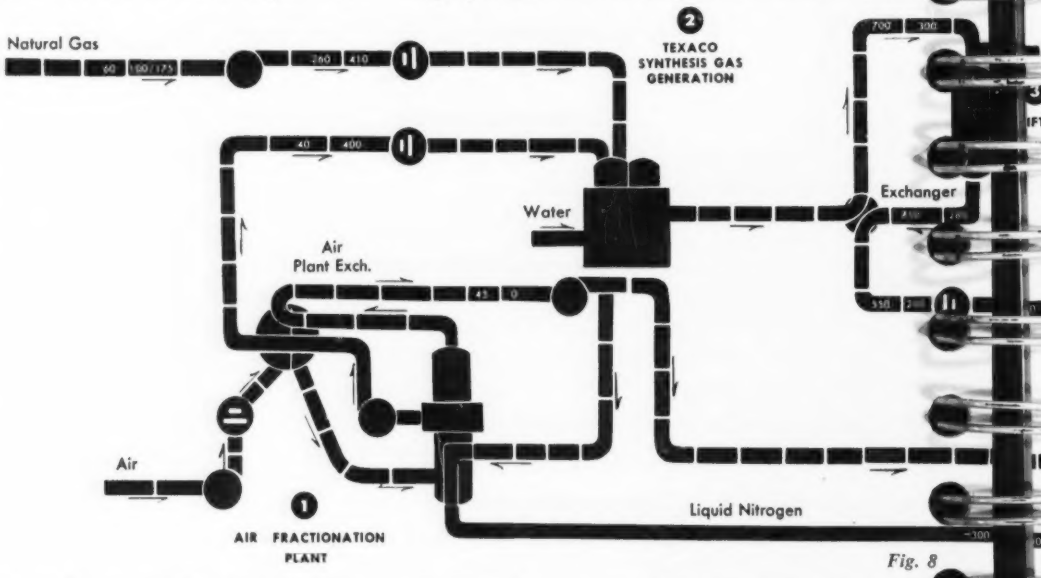


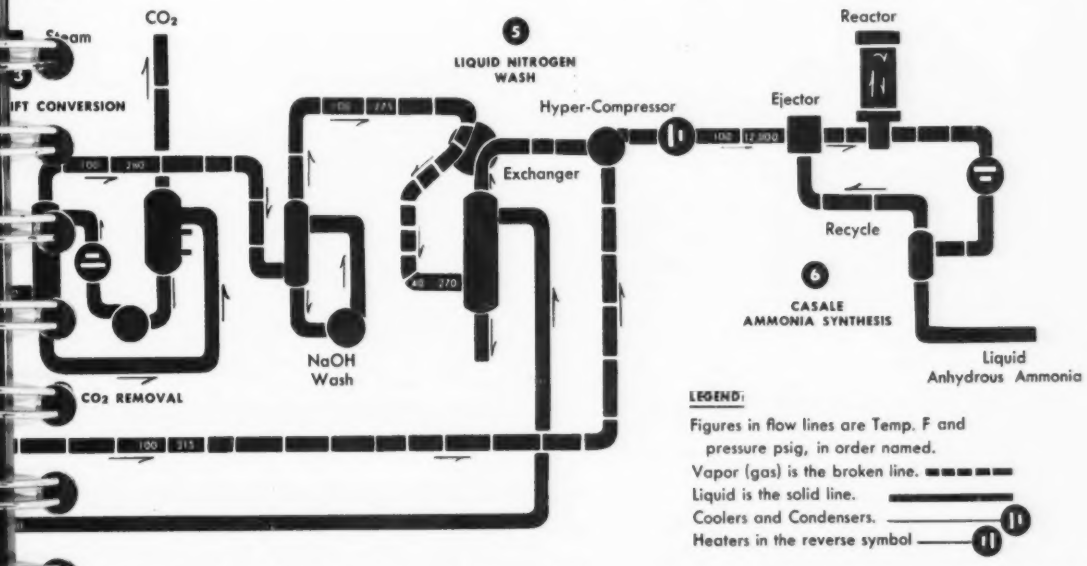
Fig. 8

Casale Ammonia Synthesis

Ammonia Synthesis: The purified synthesis gas comprising only hydrogen and whatever nitrogen was added in the nitrogen washing operation, next receives its molecular proportion of nitrogen for the ammonia synthesis stage. In the Casale ammonia synthesis process this gaseous mixture of hydrogen and nitrogen

is compressed to between 9,000 and 12,000 p.s.i.g., is cooled to about 100°F and enters the Casale reactor via the ejector system. In the reactor, which is also a heat exchanger, the nitrogen and hydrogen unite in the presence of a catalyst to form ammonia. This product of the reaction and the unconverted gases are then cooled and the liquid and gases are then separated. The unconverted gases are re-circulated through the ejector system and the liquid anhydrous ammonia is removed to storage.

Since the complete synthesis gas process requires gaseous oxygen for reforming, gaseous nitrogen for blending into ammonia synthesis gas and liquid nitrogen for scrubbing, the design of the air separation plant is integrated into a highly efficient system. No extra process-



ing space involving air or flue gas is required for the introduction of nitrogen into the system.

The Ejector System: One of the principal reasons for the world-wide application of the Casale process is that it incorporates a patented re-circulating system which uses an ejector to move the unconverted nitrogen and hydrogen back into the reactor instead of a compressor as in other processes. The action of the ejector is similar to that of a laboratory type water pump used to create a vacuum. The use of an ejector rather than a compressor for gas re-circulation has three specific process advantages. Erection cost is considerably reduced due to great simplicity in piping and the very much lower cost of the ejector in comparison to re-circulation compressors, high efficiency is achieved by minimising the leakage which cannot be avoided when using re-circulation compressors; also oil contamination into the passing gases, an inherent disadvantage of mechanical compression systems, is eliminated.

Heat Exchange: Another important advantage of the Casale process is that it incorporates a simplified heat exchanger, built into the reaction chamber, thus eliminating an outside heat exchange system and affording a simplified piping system. A high operating pressure permits production of liquid anhydrous ammonia at normal cooling water temperature and also provides greater reaction tolerance for carbon monoxide and oxygen which may be minor contaminants in the synthesis gas. As with the Texaco section of the process sequence, simplicity and flexibility together with the extensive use of instrumentation reduce the extent of laboratory control.

For economical operation using this process sequence, 100 tons a day is the minimum capacity for which a plant should be designed, while provided there are no major construction problems, 300 tons a day represents the maximum economic capacity.

Raw Materials

Perhaps the most important feature of this process sequence is that natural gas, petroleum refinery gases or fuel oil can be used as the source of hydrocarbon. These raw materials are being used in an ever increasing number of synthesis plants being built in or close to areas of consumption where coal is not readily available. This is often the case in countries which formerly imported their entire supplies of nitrogen but which are now building their own plants to make themselves self-sufficient.

Fuel oil, in particular, is a comparatively cheap source of hydrocarbon and is in most cases easier to transport than coal or even natural gas and it is certain that it will be used in an ever increasing proportion of the world's nitrogen capacity.

	Unit	*per ton Ammonia*
FEED GASES		
Natural Gas (1080 BTU/SCF)	MSCF	26.20
CATALYSTS		
Shift Reaction	lb	.23
Ammonia Synthesis	lb	.125
CHEMICALS		
Caustic Soda	lb	11.75
MEA (monoethanolamine)	lb	.40

UTILITIES	*Unit*	*per ton Ammonia*			
		(1)	(2)	(3)	(4)
Fuel Gas	MSCF	.9	.9	7.8	10.9
Steam 400 p.s.i.g. ...	lb	4650	8700	8700	4650
Steam 50 p.s.i.g. ...	lb	—	580*	580*	—
Cooling Water 80°F ...	M/gal	78	95	102	85
Electric Power ...	KWH	1120	925	58	65

(1) Compressors—Electric-driven reciprocating.
(2) Compressors—Turbo-centrifugal and motor-driven reciprocating.
(3) Compressors—Turbo-centrifugal and Gas Engine-driven reciprocating.
(4) Compressors—Gas Engine-driven reciprocating.
* Low-pressure Steam returned to unit limits.

AMMONIA FROM COKE-OVEN GAS

The Provo Plant of the Columbia-Geneva Division of the U.S. Steel Corporation

NOW IN FULL PRODUCTION, the big anhydrous ammonia and associated nitrogen compounds' plant near Provo, Utah, of the Columbia-Geneva Steel Division of the U.S. Steel Corporation is the first installation in a major steel works in the U.S.A. to use raw coke-oven gas as a source of hydrogen for ammonia.

The installations include a 200 ton per day anhydrous ammonia plant using the Montecatini process for ammonia synthesis and incorporating Linde low temperature separation processes to recover hydrogen from coke-oven gas and to extract high purity nitrogen from the atmosphere. Also included are a nitric acid plant, a 200 ton per day fertilizer grade ammonium nitrate plant and the necessary auxiliaries; an administration building for offices, a laboratory and warehouses with handling, bagging, storage and shipping facilities. Anhydrous ammonia, the key product, goes to direct sales or is further processed into nitric acid or is combined with nitric acid to form ammonium nitrate.

The entire plant was designed, engineered, procured and erected by the Chemical Plants Division of the Blaw Knox Company of Pittsburgh and was turned over to the steel

company as a complete integrated facility.

Anhydrous Ammonia

The plant manufactures anhydrous ammonia in four basic stages: (1) compression phase, (2) purification phase, (3) separation phase, (4) synthesis phase.

Compression phase: Coke - oven gas released during coking operations at the steel mill's 252 coke ovens is compressed to 150 to 200lbs. per square inch. About 50% of the gas is hydrogen, the balance being made up of hydrogen sulphide, carbon dioxide, carbon monoxide and a mixture of hydrocarbons such as methane, ethylene and propylene. The source of nitrogen is air compressed in a low temperature unit and containing about 80%N by volume. Two of the units within the compressor station are among the largest of their type installed anywhere in the world and are driven by motors rated at 6,000 horsepower.

Purification phase: From the compressor the coke-oven gas goes to scrubbing towers for removal of carbon dioxide and hydrogen sulphide. An ammonia-water solution is used which causes the carbon dioxide and hydrogen sulphide to break down and combine with ammonia. Thus, solutions of ammonium carbonate and ammonium sulphide are formed which are drawn off and subjected to mild steam heating. The gases then decompose and are stripped out and the ammonia is recovered for re-circulation. Carbon dioxide and hydrogen sulphide are then separated, the former being released into the atmosphere.

The hydrogen sulphide goes to a small integrated unit for production of sulphuric

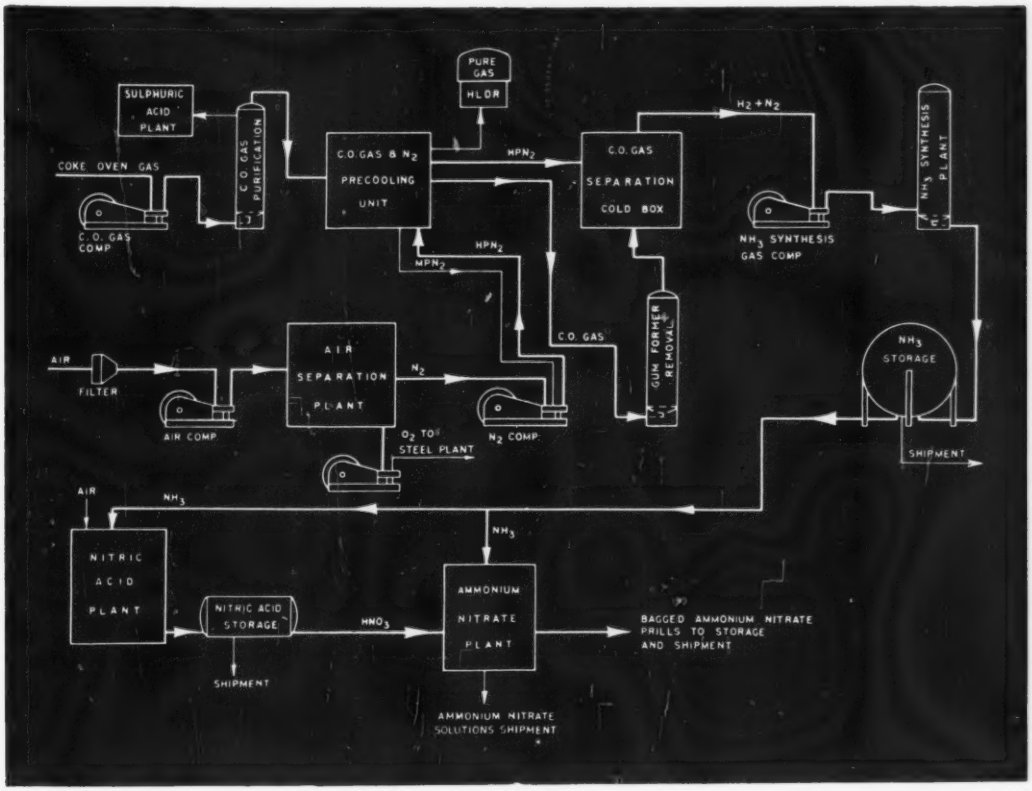


Fig. 9 Flow diagram.

acid by a wet catalysis process. Approximately 50 tons of sulphuric acid are formed per day and this is piped to the existing by-products operation at the steel mill.

Separation phase: After removal of carbon dioxide and hydrogen sulphide, the coke-oven gas is cooled before being subjected to a special gum former removal process which is designed to filter out nitrous oxide and other acid gas residues. These must be removed otherwise, later on, they would congeal and block the low temperature equipment. Traditionally, gas separation equipment operates as a separate unit and being subject to fouling can cause a shut-down of the entire plant. The gum former removal stage at the Provo plant is unique, however, and special equipment which includes a tower enables the operation to function without interruption and as an integrated part of the separation phase.

After passing through the gum former removal equipment, the gas stream moves into the coke-oven gas separation unit consisting of several "cold boxes" which reduce the gas temperature to −320°F and turn it into liquid form. The insulation of the "cold boxes" against the extreme low temperatures requires 500 tons of rock wool crammed between the pipe work. Hydrogen is separated and drawn off and the remaining gases, methane, carbon dioxide, ethylene, etc., which were present in the original supply are piped back to a gas holder in the steel plant and used as high purity fuel in steel making operations. Removal of hydrogen, which is low in B.T.U. value, ensures that the gas returned to the steel plant is high in methane content and is a greatly improved fuel over that which originally left the coke ovens.

Air separation takes place concurrently with the gas separation. From the compressor, the air stream passes into the separation cold box where it is liquified at between −290°F and −300°F when separation of nitrogen and oxygen takes place.

Oxygen goes to the steel works where it is primarily used for metallurgical purposes, while the high purity nitrogen coming from the low temperature air separation cold box is compressed to about 3,000lbs. per square inch. It is then introduced, in gaseous form, to the coke-oven gas low temperature cold boxes where it mixes with hydrogen at the rate of one part nitrogen to three parts hydrogen to form a synthesis feed gas for ammonia production.

Synthesis phase: The feed gas is compressed to about 5,000lbs. per square inch and conveyed to the synthesis converter where hydrogen and nitrogen are mixed in the presence of an iron base catalyst in granular form. Not all the gas is converted in the initial contact, the ammonia formed being drawn off and the unreacted portion of the feed is passed through recycle injectors which reintroduce it to the catalyst. By eliminating the recycle compressors normally required, investment costs and maintenance work, which otherwise would be required by moving parts of compressors at this point, are reduced.

An initial heat source is necessary to start the reaction with the catalyst, but once this begins, the exothermic heat generated chemically keeps the catalyst at the required temperature. Excess heat produced is passed to a waste heat boiler and is used to heat water, generate steam and perform other functions within the plant.

Pure ammonia from the synthesis tower is piped as a liquid to storage in one of two Horton spheres, each 60ft. in diameter, where it is kept in its liquid state at a pressure of 60lbs. per square inch and a temperature of 40°F.

Nitric Acid Production

Ammonia required for nitric acid processing is introduced to the nitric acid plant at medium pressure and is burned with air in the presence of a platinum catalyst at temperatures approaching 1,500°F. The resulting nitric oxide is then exposed to oxygen and after passing through an oxidation column it emerges as nitrogen dioxide. This is introduced to the cascade absorber tower comprising 20 stainless steel tanks connected in series and containing water. As the nitrogen dioxide bubbles up through the water, the compounds combine to form nitric acid of 53% strength. Cooling water cascading down over the exterior of the tanks helps to carry off excess heat generated during the chemical reaction.

Aerial view of Columbia-Geneva Works at Utah, of U.S. Steel Corporation, showing the new nitrogen plant in the foreground. (1) steel mill; (2) coke oven gas lines; (3) general service building; (4) compressor station; (5) gas purification and separation area; (6) pure gas holder; (7) synthesis tower; (8) Hortonspheres; (9) cooling towers; (10) nitric acid unit; (11) prilling towers; (12) nitrate drying and bagging facilities; (13) warehouse and storage building.

From this point the product is used, either for the production of ammonium nitrate, or is further processed into high strength nitric acid for direct sales. When used for the latter purpose it is concentrated in a vapourising column where excess water is boiled off to bring the finished product up to between 63% and 67% strength.

Ammonium Nitrate Production

The first stage in the process is to neutralize the liquid ammonia with nitric acid to form an ammonium nitrate salt solution.

Concentration phase: The solution enters an evaporator of standard design where it is concentrated. Some of the solution which is at 83% strength is drawn off as ammonium nitrate for sale in liquid form. The remainder is further concentrated to 96% before being piped to the top of the nearby 200ft. tower. The solution enters the tower through a spray system which breaks it into droplets which fall against a counter current of cooling air and are converted into prills.

Drying and finishing stage: On striking the floor of the tower, the prills are removed by conveyor belt to a three-stage rotary kiln consisting of a pre-drier, a drier and a cooler. On emerging from the cooling unit the prills are rolled through a drum containing powdered diatomaceous earth. This sticks to them and retards absorption of moisture thereby preventing caking.

Conclusion

In addition to meeting an important demand for fertilizer materials, the new plant is supplying substantial quantities of ammonium nitrate, ammonia and nitric acid for industrial applications in Utah and neighbouring states. Ammonium nitrate prills, intended originally for use in agriculture have found a second role

as an industrial explosive in strip mining and heavy construction activities when combined with a carbonaceous medium. Ammonia and nitric acid are extensively used in the concentrating of uranium ores in the Colorado Plateau area, while nitric acid is used to refine further the uranium concentrate into a nuclear fuel and in the recovery of man-made fission fuels from breeder reactors.

The vast mining deposits of the area, still largely undeveloped, contain virtually all the basic organic and inorganic materials needed for a wide range of chemical products and there can be no doubt that the nitrogen produced at this important plant will play a key role in the development of Utah's agriculture and the growing chemical industry of the inter-mountain West.

MODDERFONTEIN

Self-Sufficiency of Nitrogen Supplies in South Africa

EXTENSIONS, involving an outlay of over £10 million, are now being carried out at the Modderfontein plant of African Explosives & Chemicals Ltd. which will raise installed ammonia capacity to 145,000 tons a year and which include a urea plant with an annual capacity of 110,000 tons.

The company started production of synthetic ammonia at Modderfontein in 1932. The synthesis gas was obtained by the gasification of metallurgical coke in cyclically operated semi-water gas generators. This plant was extended as demand increased until by 1950 the capacity was 25,000 short tons of ammonia a year. Throughout this period the nitrogen output was wholly devoted to the manufacture of explosives and in this field the Modderfontein plant was one of the largest in the world.

In 1954 a completely separate unit with a capacity of 40,000 short tons a year was commissioned and was extended the following year to a maximum capacity of 50,000 tons. As in the first unit, synthesis gas was obtained in fixed bed dry base generators with cyclic semi-water gas operation, the ammonia synthesis being carried out in a Haber-Bosch plant at a working pressure of 350 atms. In designing this No. 2 ammonia plant, great attention was paid to the purity of the gases and sulphur removal is effected in gas-tight reinforced concrete scrubbing boxes which are among the largest of their type in the British Commonwealth. Carbon dioxide is removed in scrubbing towers of over 90 feet in height built by the Vecor works in the Transvaal. High pressure steel vessels used in this plant were fabricated by the new strip wound process, being lighter and less costly than the older drop-forged type. The bulk of the ammonia produced at Modderfontein before the current extensions began was used in the manufacture of nitric acid and ammonium nitrate.

The increases in capacity made in 1954 and 1955 were primarily intended to raise the production of nitrogenous fertilizers, but the expanding gold mining and uranium industries required large quantities of anhydrous ammonia and weak nitric acid with the result that relatively little output remained available for agriculture. In 1956 only 14,000 tons of ammonium nitrate (4,650 tons of nitrogen) were sold as fertilizer material.

Future Demand

Early in 1955 a complete survey was carried out of the future demand for nitrogen in Southern Africa and estimates showed that by 1962 the position would be as follows :—

Supply	*tons nitrogen per year*
From steel works and SASOL ...	20,000
Available capacity at Modderfontein	62,000
	82,000
Demand	
For explosives and industrial purposes	60,000
For fertilizers in South Africa ...	60,000
For fertilizers in the Central African Federation	20,000
	140,000
Extensions required	58,000

In order to study the latest developments in coal gasification and in the manufacture

of ammonia and nitrogen fertilizers, a "Nitrogen" mission from the company conducted a series of visits to many countries, including the United Kingdom, America, Germany, Finland, Holland and Japan. In the light of the findings and cost estimates it was decided that the most satisfactory and economical method of obtaining increased nitrogen capacity would be an extension of the No. 2 ammonia unit from its present capacity of 50,000 tons to one of 120,000 tons a year.

As the supplies of coking coal in the country were limited and were needed by the steel industry, it was agreed at the outset that the vast reserves of low grade Transvaal coal should be considered as a source of hydrogen for the manufacture of ammonia. After extensive investigations into various gasification processes, it was agreed that under A.E. and C.I.'s conditions, the most satisfactory method would be to convert the low grade coal by low temperature carbonisation into a char or semi-coke, which, in conjunction with oxygen and steam, would be used to produce the synthesis gas.

Further investigations were made into the nitrogen fertilizer requirements of South Africa and the Central African Federation and it was decided that the most satisfactory and economical fertilizer to produce would be urea in the form of a prilled solid and in the form of a urea-ammonia liquor. All the extensions to Modderfontein were announced in July 1957 and it is estimated that some sections will be in operation by October of this year, the whole project being completed by June 1960.

General view of the No. 2 ammonia plant at Modderfontein and the site of the new 110,000 tons per annum urea plant.

PROCESS UNITS

Low Temperature Carbonisation. The plant for low temperature carbonisation is being supplied by the Lurgi G.m.b.H. of Frankfurt a/m who developed the process originally for the coking of brown coal and who on this project are working in conjunction with their local agents, Industrial Machinery Supplies Ltd. of Johannesburg. The plant consists of two units with a rated capacity of 800 metric tons of coal and 600 metric tons of semi-coke. The tail gas produced will be used, together with any coke and coal fines in a new steam raising plant now being erected.

Before the decision to purchase this type of carbonisation plant was taken, 100 tons of low grade coal were shipped from the Transvaal to Western Germany where the Lurgi Company arranged for it to be tested on a commercial basis and it was charred on an existing low temperature carbonisation plant and the semi-coke was subsequently gasified.

When the new extensions are in operation, of the total ammonia capacity of 145,000 tons a year, only 25,000 tons will be based on the use of metallurgical coke.

Oxygen. The oxygen required for the gasification of the semi-coke at Modderfontein will be obtained from two 150 tons per day air separation units supplied by British Oxygen Linde. These units will produce 275 tons of oxygen and 285 tons of nitrogen a day. Much of this plant is actually being built by Linde of Germany and both Linde companies are working through their local agents, African Oxygen Ltd. of Johannesburg.

Gasification. The modifications to the existing gas generators and the installation of two new generators are being carried out by Ashmore, Benson, Pease & Co. of Johannesburg to the designs of their associate, the Power Gas Corporation Ltd. of Stockton-on-Tees. The detailed engineering, supply and erection of the extensions to the gas purification section of the existing plant are being carried out by Power Gas in accordance with basic design data supplied by African Explosives and Chemical Industries of the Billingham Division and Imperial Chemical Industries Ltd. These extensions comprise equipment for carbon monoxide conversion at low pressure, carbon dioxide removal and recovery using water wash and high pressure carbon monoxide removal using copper liquor wash and final purification.

Ammonia Synthesis. The increase in the ammonia capacity of the No. 2 unit will be met by a new synthesis section of the Haber-Bosch type working at a pressure of 350 ats. and of similar design to the existing installation.

Urea. About 40% of the ammonia produced at Modderfontein will be in the manufacture of prilled urea in a plant with a capacity of 110,000 short tons a year, built and erected by Werkspoor N.V. of Amsterdam to the design of Stanicarbon of Geleen, Holland. A partial recycle process is to be used and the small amount of surplus gas produced will be used in the existing ammonium nitrate plant.

Nitric Acid. Before the current extensions, the nitric acid plant at Modderfontein comprised three ammonia oxidation units, two being of the Du Pont pressure type operating at 100lb. per sq. inch while the third is of Dutch design and operates at a lower pressure. The capacity of this plant is about 90,000 tons annually. The bulk of the acid is used at the factory for nitration processes in the explosives section and in ammonium nitrate production although considerable amounts of acid are also supplied to the new uranium extraction plants at various gold mines on the Rand and in the Orange Free State.

Extensive provision for power and waste heat recovery is a feature of the nitric acid plant which also incorporates the first gas turbine to operate in the Union. This turbine is run entirely on the waste stack gases which are still under pressure after oxides of nitrogen have been absorbed by water to form acid. Supplied by Escher-Wyss of Switzerland, the turbine is a three-stage impulse model and is directly coupled to a seven-stage rotary air compressor driven at 8,890 r.p.m. through a step-up gearbox by a 2,200 h.p. 1,500 r.p.m. synchronous electric motor. The air compressor replaces the reciprocating type formerly used to supply air to the oxidising chambers and power savings of up to 50 per cent have

been reported through the use of the latent power of the waste gases in this manner.

To accompany their present extensions, African Explosives and Chemical Industries have installed a further 150 tons per day plant which was integrated with the existing installation. Constructed by Chemical Industrial and International Ltd. of Nassau, Bahamas, to the design of their associate company of Cincinnati, Ohio, the new plant is of that company's standard high pressure type operating at approximately 100lb. per square inch. It is equipped with an electric motor-driven centrifugal compressor and expander turbine.

Ammonium Nitrate. The ammonium nitrate section of the Modderfontein factory is designed for a production of 200 tons per day. The neutralising vessels used are of low pressure type and concentration of ammonium nitrate solution is carried out in automatically-controlled falling-film type evaporators.

Self Sufficiency

The Modderfontein plant is the principal source of nitrogen in South Africa and by 1960 will account for about 90% of production. The South African Iron and Steel Industrial Corporation (ISCOR) recovers ammonia as a by-product at Pretoria and Vanderbijl Park, while the South African Coal Oil and Gas Corporation Ltd. (SASOL) coal-to-oil project at Sasolburg is another important potential source of ammonia. Owing to technical difficulties during the start-up period and in view of the delay in commissioning auxiliary installations, so far only comparatively small quantities of ammonia liquor have been supplied. However, by 1960 the combined production of ISCOR and SASOL should be in the region of 15,000 tons of nitrogen a year.

Although demand for nitrogen in both agriculture and industry can be expected to grow steadily, the current extensions at Modderfontein should make South Africa independent of external supplies for several years to come.

AMMONIA SURPLUS IN THE WEST

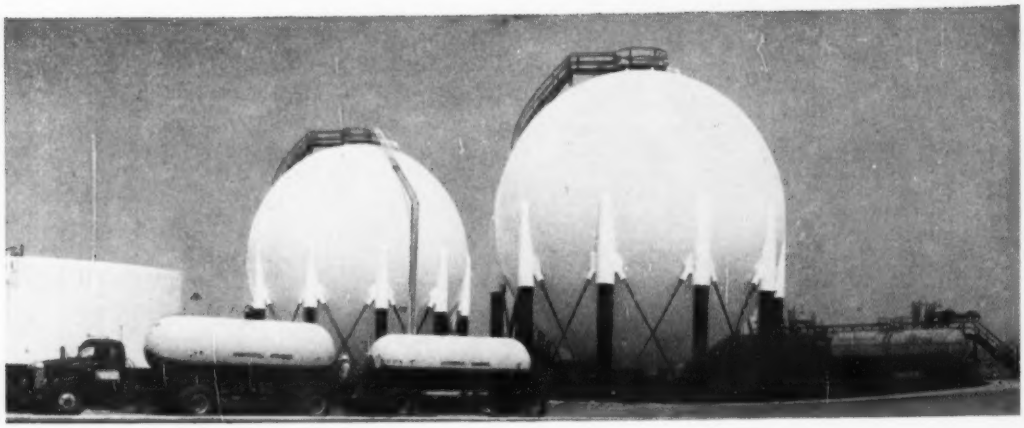
The present ammonia capacity in the 11 Western States is represented by the following plants :—

	Amm. cap. t.p.a.
Collier Carbon & Chemical, Brea, Calif.	86,000
Dow Chemical, Pittsburg, Calif. ...	9,100
Hercules Powder, Pinole, Calif. ...	50,000
Hooker Chemical, Tacoma, Wash.	22,000
Pennsalt Chemicals, Portland, Ore.	7,000
Phillips Pacific Chemical, Finley, Wash.	73,000
Shell Chemical, Pittsburg, Calif.	112,000
Shell Chemical, Ventura, Calif. ...	75,000
Standard Oil of Calif. Richmond, Calif	109,500
U.S. Steel, Geneva, Utah. ...	73,000
Apache Powder, Benson, Ariz. ...	11,000
Total	627,600

The demand for ammonia, both in agriculture and industry, has been growing fast in the Western States and producers have steadily increased their capacity to meet this demand. Recently, however, a surplus of capacity has become evident in that with annual consumption at a level of 300,000 tons installed, capacity has risen to double that amount and this threatens to upset the stability of the market. In spite of this, one large plant is under construction and plans are being made to build more.

The California Ammonia Company, organised by a large group of farmers in the San Joaquin valley in co-operation with the Best Fertilizers Co., has recently completed a plant at Lathrop with an annual capacity of 40,000 tons of anhydrous ammonia. Estimated to cost $4.6 million, the new plant uses hydrogen produced by the steam reforming of methane.

Another nitrogen fertilizer works in the San Joaquin valley will be the $8½ million plant of Valley Nitrogen Producers Inc. Due for completion in November 1959, this plant will have a capacity of 50,000 tons of anhydrous ammonia a year and will be managed by the Mississippi Chemical Corporation. Perhaps in an attempt to discourage Valley Nitrogen from going ahead with its plans, the California Ammonia Co. has announced that in the next off-season starting in August 1959 it would offer ammonia at $63 a ton, some $30 a ton less than the current price in the West.



Brea Chemical Co. Anhydrous Ammonia storage and rail/road loading facilities.

Not deterred by these increases to California's nitrogen capacity, two other firms have announced or are considering extensions to their plants. The Standard Oil Co. of California are raising the capacity of their plant at Richmond from 300 to 330 tons of anhydrous ammonia a day. This company sells ammonia produced at Richmond to its subsidiary, the California Spray Chemical Corp., which uses it in the manufacture of fertilizers. The Collier Carbon and Chemical Corp. is reported to be considering an expansion of its Brea, California, plant from its present capacity of 86,000 tons to one of about 125,000 tons of ammonia a year.

The following table is a summary of extensions to capacity, recently completed, under construction or planned :—

	Amm. cap. t.p.a.	*expected completion*
California Ammonia, Lathrop, Calif. ...	40,000	completed late 1958
Valley Nitrogen Producers, Fresno, Calif.	50,000	November 1959
Standard Oil of California, Richmond, Calif. ...	11,000	early 1959
Collier Carbon & Chemical, Brea, Calif.	39,000	1960
Southwestern Agrochemical, Chandler, Ariz.	21,000	1960
	161,000	

The present expansion of nitrogen capacity in the West is not confined to California. After rumours to the contrary, it has recently been announced that the Southwestern Agrochemical Co. will go ahead with their plans for a 60-ton per day ammonia plant at Chandler, Arizona. They are to build and operate this project, estimated to cost $4 million in conjunction with the First Mississippi Corporation.

Although the companies which are building or have recently completed nitrogen plans in the West claim to have secured an outlet for their products, the market in this area does not appear to be on a sound basis, and if it were subjected to heavy pressure several of the well-established producers, particularly those with large and flexible capacities, could flood the market with ammonia at a very competitive price. Even if ammonia capacity in the West is not expanded further than is at present planned, it is unlikely that it will be balanced by consumption before 1965.

When all the new plants are in operation, ammonia capacity in the 11 Western States will amount to almost 24% of the total United States capacity, whereas consumption in this area, even if it were to continue increasing at the present rate for the next three years, cannot be expected to exceed 14% of the United States total. This situation has been created at a time when an appreciable surplus capacity amounting to nearly one million tons N already exists in the United States as a whole and shows no signs of disappearing.

THE COMMERCIAL PRODUCTION OF GASEOUS NITROGEN

GASEOUS NITROGEN, accounting as it does for four-fifths of the earth's atmosphere, has naturally attracted the attention of many great men of chemistry. It was termed "foul air" by Scheele in 1772, azote (Greek: "no life"), by Lavoisier in 1775, phlogisticated air by Priestley, and nitrogen by Chapital in 1790.

Nitrogen now finds wide and ever increasing use industrially where its inertness is of great value in protecting chemical or metallurgical processes against oxidation. These processes will be only broadly outlined in this article, but more detail will be given from time to time in further issues of this magazine.

The industrial demand for nitrogen may be divided broadly into three groups:—small scale (approximately 50-250 S.C.F.H.), medium scale (250 - 50,000 S.C.F.H.), and large scale (above 50,000 S.C.F.H.). Economics dictate that a different means of production is employed for each of these ranges. For the lowest range, nitrogen may be conveniently prepared from anhydrous ammonia, which may be regarded as a chemical method. The medium range uses air, but is again essentially a chemical method where the oxygen is removed by combustion of fuel gas or oil and the products then separated by chemical means. Large scale production is basically accomplished by a purely physical process, namely fractional distillation of liquefied air, although additional purification by chemical means is also practised.

For small intermittent usage there is no more convenient source than the cylinder which, containing 165 cu. ft. of high purity nitrogen and generally including a trace of oxygen, is commonly used in chemical and physical laboratories of all types. Other methods are of course used in school and college laboratories, as for example the reaction of some ammonium compounds, but these cannot be considered seriously as production methods.

Small Scale Production (50-250 S.C.F.H.)

Ammonia, a compound of hydrogen and nitrogen, offers a useful source of nitrogen, for it is relatively simple to remove the water formed by combustion of hydrogen thereby leaving pure nitrogen, i.e.

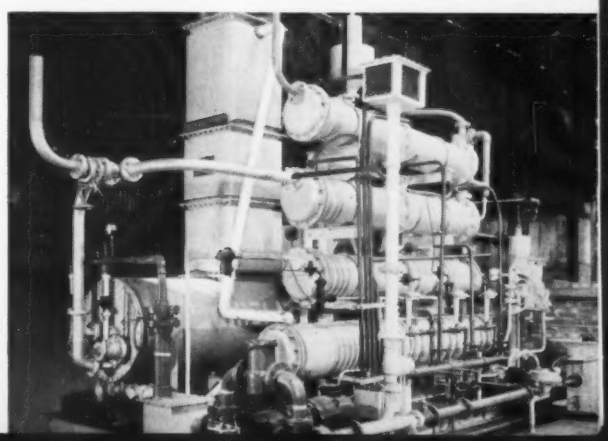
$$2NH_3 = N_2 + 3H_2$$
$$N_2 + 3H_2 + 1\tfrac{1}{2}O_2 + 6N_2 = 7N_2 + 3H_2O$$

This may be either a two-stage process where separate cracker and burner are used—a method which has found favour in the past—or the recently introduced single stage catalytic process where both the above reactions proceed simultaneously. High pressures and moderate temperatures and the influence of a catalyst promote the reaction between hydrogen and nitrogen in ammonia synthesis, whereas at atmospheric pressure sponge iron is active at 525°C and promotes the dissociation of this compound. A special regenerative burner is frequently used for the combustion of this hydrogen-nitrogen mixture so as to remove traces of oxygen from a recirculated nitrogen stream and allow the use of a small generator on quite sizeable installations. The catalytic process utilises either a precious metal catalyst or one recently developed by the Incandescent Heat Co. of Birmingham. Nitrogen produced from ammonia costs about 10s. per 1,000 cu. ft., allowing only for power and cost of ammonia.

Medium Scale Production (250 C.F.H.-50,000 C.F.H.)

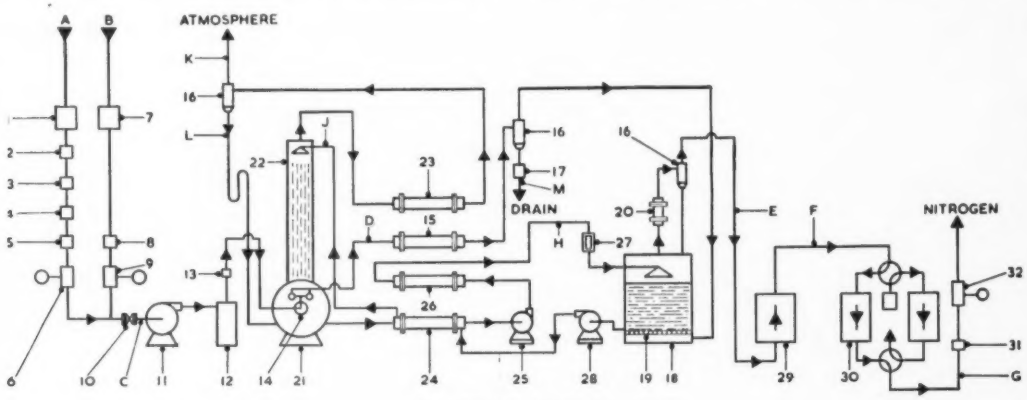
Practically and economically, the best way of producing nitrogen in this range is by the combustion of a fuel gas with air. In this way

Incandescent Nitrogen Generator. Output 4,000 cu. ft. per hour.



the oxygen is reacted completely to give water vapour and carbon dioxide. The removal of the former relatively simple and indeed much is precipitated during cooling. The cooled gas has an average composition of 12% CO_2 and 88% N_2 fully saturated with water vapour. Removal of carbon dioxide may be effected in various ways, depending on the desired purity of the final nitrogen. Generally an ethanolamine solution is used for this process as it possesses the property of bicarbonate formation with subsequent breakdown to the carbonate and carbon dioxide when boiled. Final drying may also be effected in a variety of ways, including refrigeration, compression and drying through activated alumina, silica gel, molecular sieves or other suitable dessicant beds.

Town gas, coke-oven gas, natural gas, methane, propane or other gaseous hydrocarbon mixtures of reasonably constant composition is burnt with a carefully measured quantity of air through a special burner firing into a totally immersed combustion chamber. The heat of combustion is then used to boil the recirculating monoethanolamine to reactivate and remove carbon dioxide through the stripper tower. Fig. 10 illustrates this process. After cooling the products of combustion, carbon dioxide is absorbed in a tower through which the amine solution is circulated, and nitrogen, containing only water vapour, leaves the plant through a cooler and spray separator located above the absorber. When further purification is required a refrigerator is used to remove water vapour down to a dewpoint of about 40°F. Alumina filled towers used alternately are also provided to reduce the final water content down to a dewpoint of below—40°F. The complete unit is of compact design and operating costs are only about 3s.-3s. 6d. per 1,000 cu. ft. of nitrogen produced.



Flow diagram for nitrogen generator

Key

EQUIPMENT

1. Gas Filter
2. Gas Pressure Switch
3. Gas Solenoid Valve
4. Zero Governor
5. Gas Limiting Orifice Valve
6. Gas Flowmeter
7. Air Filter
8. Air Limiting Orifice Valve
9. Air Flowmeter
10. Non-return Valve
11. Air–Gas Booster
12. Oil Trap
13. Flame Trap
14. Burner
15. Gas Cooler
16. Gas Liquid Separator
17. Steam Trap
18. Carbon Dioxide Absorber
19. Porous Plates
20. Gas Aftercooler
21. Reboiler
22. Stripper Tower
23. Condenser
24. Amine Heat Exchanger
25. Lean Amine Pump
26. Lean Amine Cooler
27. Lean Amine Flow Indicator
28. Rich Amine Pump
29. Refrigerant Dryer
30. Activated Alumina Dryer
31. Nitrogen Pressure Governor
32. Nitrogen Flowmeter

MATERIAL FLOW

A. Raw Gas
B. Air
C. Air–Gas Mixture
D. Burned Gas
E. Nitrogen Dewpoint $\leq$ 100° F.
F. Nitrogen Dewpoint +40° F.
G. Nitrogen Dewpoint $\leqslant$ − 40° F.
H. CO_2 "Lean" Amine
J. CO_2 "Rich" Amine
K. CO_2
L. Amine Condensate Return
M. Water of Combustion

Fig. 10.

Town gas, coke-oven gas, natural gas, methane, propane or other gaseous hydrocarbon mixtures of reasonably constant composition is burnt with a carefully measured quantity of air through a special burner firing into a totally immersed combustion chamber. The heat of combustion is then used to boil

On some occasions carbon dioxide forms a useful by-product from this type of nitrogen generator, for this gas also has many industrial applications.

Large Scale Production

It is difficult to decide exactly at what point the physical methods of separation, i.e.

the distillation of liquefied air, offer advantages over the chemical methods as previously described. Air is one of the few raw materials which costs nothing; electrical power, however, may represent a greater expenditure than, for example, waste refinery gases. When very large liquefaction plants are considered, much of the energy can be conserved by the use of heat exchangers. Another advantage of liquefaction plants lies in the fact that oxygen is obtained as a by-product. Many tonnage oxygen plants are operating throughout the world, often with an equivalent hourly output of approximately ½ million cu. ft. nitrogen; some of this is, however, often blown to waste.

Uses of Nitrogen

By far the largest use of nitrogen is, of course, in the manufacture of ammonia where combination with hydrogen is effected by the action of heat, pressure and a suitable catalyst. However, there are other uses which, although relatively minor in comparison, are none the less important.

Metallurgical. Practically all metallurgical processes use nitrogen in some way on account of its inert properties. However, there are one or two very important uses where nitrogen plays an active part in the process. Nitriding and carbonitriding are good examples of this, for in each case nitrogen derived from ammonia reacts with steel to give an iron nitride surface which is extremely hard and possesses great resistance to wear. Crankshafts, layshafts and other parts which would normally experience a great deal of wear are protected in this way. In carbonitriding, a related process which is fast growing in popularity due to its far greater speed, both carbon and nitrogen are taken into the steel simultaneously. One factor which plays an important part in both these processes is the catalytic action of iron—the principal constituent of the material being treated. This promotes the dissociation of ammonia into its component elements.

Earlier in this article mention was made of small nitrogen plants depending on the combustion of dissociated ammonia; the type of process in which these may be found varies widely. The annealing of stainless steel is one application, for here any trace of carbon monoxide, carbon dioxide or water vapour would cause discolouration due to oxidation of the chromium. Metal parts made of compressed powders are sintered in a cracked or burnt ammonia atmosphere, i.e. either a hydrogen/nitrogen mixture or relatively pure nitrogen. Small components of steel may be brazed together under a protective atmosphere of nitrogen.

When the plants with larger outputs are considered, more metallurgical applications are possible. Steel at high temperature is a rather peculiar material, for it enters into reaction with the most unlikely materials. For instance, carbon dioxide is normally considered very inert but it roughens the surface of hot steel and increases the catalytic activity of that material, removing at the same time some of the carbon to give carbon monoxide. This gas breaks down into carbon dioxide and soot and in consequence the steel leaves the furnace rather dull and blackened.

Chemical. Nitrogen finds wide use in blanketing chemical reactions to prevent oxidation, and is also used to agitate corrosive or highly reactive liquids. Its inertness and inability to support respiration have aroused interest in the storage field where damage by rodents and moths is completely prevented. Here nitrogen offers a distinct advantage over carbon dioxide (or its admixtures with this gas) for in carbon dioxide some moulds and fungi will grow, and fruit will ripen.

In some of the applications mentioned pure nitrogen is essential, while in others 99% purity is required. This raises an interesting point for when producing nitrogen by chemical means it is necessary to state whether a trace of oxygen or reducing gases is objectionable. If oxygen can be tolerated, air in slight excess is used in a combustion process. If only the presence of reducing gases is permissible or perhaps even an advantage, then a slight deficiency of air is required. When town gas of variable composition is used as the combustible material, the purity of nitrogen produced cannot be specified within close limits, and where close control is required on medium sized installations it is usual to use propane, which is available in a relatively pure form at low cost. In this respect propane offers some

slight economic advantages over town gas in most areas of the United Kingdom.

Whilst mentioning impurities, it is essential to consider the influence of water vapour, which is a product of the combustion of hydrogen or of a hydrogen-containing compound. In many processes in organic chemistry or metallurgy water is deleterious, and must therefore be removed from the nitrogen. For this purpose dessicant-filled towers are arranged in pairs so that one may be in use while the other is regenerated by heating. The towers are filled with activated alumina, dessicant silica or molecular sieves, and hot gas for reactivation is provided by an integral heater. Changeover between towers may be either manual or automatic.

Whereas in combination with other elements, nitrogen produces highly reactive compounds such as ammonia or nitric acid, it is by itself remarkably inert. Only a few uses of nitrogen arising from this property have been mentioned and many other applications are constantly being developed.

We are indebted to Mr. I. L. S. Golding, of the Incandescent Heat Co. Ltd., for information and illustrations placed at our disposal.

INDUSTRIAL NITROCELLULOSE

Its manufacture and application

IN 1845 Schonbein prepared nitrates of cotton cellulose and a few years later the method of production was published by Otte, thereby laying the foundation of the nitrocellulose industry. Its original use was in the form of collodion (an ether-alcohol solution), as a protective dressing for wounds. Later it was used in photographic emulsions but without marked success. However, the applications have changed over the years and now a considerable amount of material is used in the lacquer and paint trades.

The commercial exploitation of nitrocellulose as an explosive began as early as 1847 and it has since been used as a component of blasting gelatine, cordite and dynamite. In parallel, its peace-time use in the manufacture of celluloid was developed, and this led to the incorporation of the British Xylonite Company in 1877. Despite the introduction of newer plastics more Xylonite or celluloid were used in 1957 than ever before. The use of nitrocellulose in surface coatings of various descriptions has steadily increased, particularly in the manufacture of furniture, household fittings and motor cars.

METHOD OF MANUFACTURE

Nitration

In the industrial process, dried cellulose is esterified to the nitrate by a large excess of mixed nitric and sulphuric acids at a temperature of approximately 100°F. Two cellulosic raw materials are suitable, cotton linters and wood pulp. Replacement of hydroxyl groups of the glucose residues in the chain takes place, and the degree of nitration is determined mainly by the composition of the acid bath. Complete nitration may be represented as the trinitrate $C_6H_7O_2(NO_3)_3$, which contains 14.15% nitrogen. The actual nitrogen content determines the explosive nature of the nitrocellulose and also its behaviour in various solvents. This factor is of critical importance to the user, and the industrial material is sold within certain limits, "High" 11.8-12.2% nitrogen, "Medium" 11.3-11.7% and "Low" 10.8-11.2%. As nitrocellulose sold for industrial purposes does not contain more than 12.2% of nitrogen, it is not classified as an explosive.

Nitration takes place in stainless steel vessels; the charge is then centrifuged, the spent acid is removed and the nitrocellulose cake drowned with water. The physical form of the material is not changed.

Purification

Each quenched charge is pumped to a stabiliser vessel. A series of washings take place using treated water to remove adhering acid and to decompose and remove unsuitable material.

The water used in these stages is pretreated and filtered to remove iron and other

inorganic matter which would otherwise contaminate the nitrocellulose. All plant in contact with the product is made of stainless steel or other corrosion resisting material.

Digestion

For many applications nitrocellulose must have a low solution viscosity and to achieve this the slurry of nitrocellulose is boiled under pressure in weak acid. Further washing is then necessary to remove decomposition products formed during this operation.

Dehydration

Two methods of dehydration are practised, depending upon the physical form of the product.

The fibrous or linters form of nitrocellulose is placed in a draining stall to remove as much water as possible. It is then loaded into a press, and more water is removed under pressure through the upper platen. Spirit is pumped into the lower platen and through the "cheese" of nitrocellulose, thereby displacing the residual water. The spirit-wet block is given a final press to reduce the spirit content to approximately 25% and is then removed from the press for sifting.

In the dehydration of "dense" wood pulp material, the slurry of pellets is fed to a horizontal multi-stage basket centrifuge. In the first section most of the water is removed. The pellets are transferred to the next section of the basket by a reciprocating mechanism and here they are sprayed with spirit of increasing strength. If the nitrocellulose is required in the water-wet condition, the displacement stage with spirit is omitted.

The approved damping agents are : water, industrial methylated spirits, isopropanol and butanol, and the usual ratios of nitrocellulose to damping agent are 70 : 30 and 65 : 35. In this way the product conforms with the limitations imposed by the Explosive Acts of 1875.

GRADES AND APPLICATIONS

The high nitrogen grades have the widest range of applications for they are characterised by solubility in esters and ester-hydrocarbon mixtures, i.e., the cheaper solvents, and they are of particular interest to paint, lacquer and ink manufacturers.

Medium grades are favoured by producers of cast cellulose film when protective moisture-proof surface coatings are required. These characteristics are essential when the film is required for food-wrapping purposes. The heat sealing properties of the film depend, amongst other factors, upon the nitrogen content of the nitrocellulose.

Grades with low nitrogen content are used in the coating of leather-cloth and in considerable quantity in the production of celluloid.

In addition to nitrogen content, the manufacturer also classifies his material by its viscosity in various solutions. The standard

Washing Nitrocellulose.

A.S.T.M. formulation contains 12.2% dried nitrocellulose in a solution of methylated spirits, ethyl acetate and toluol. High viscosities are measured by the time of fall of a steel ball through the solution and are calculated in seconds. Lower viscosity grades are measured in a capillary viscometer and the result is calculated in centiposes (377 cP per sec.) The determination of viscosity is of great importance, for the solids content, the elongation and the tensile strength of the cast film are dependent upon it.

Material of the highest quality must be obtained in the manufacture of nitrocellulose for use in the production of lacquers, paints, solvents, plasticisers and resins. In these, as in many other fields, nitrocellulose is assuming an increasingly important rôle.

We are indebted to Messrs. N. E. Bean B.A. and A. Lofthouse B.Sc. A.M.I. Chem.E. of BX Plastics Ltd. for information and illustrations placed at our disposal.

current events

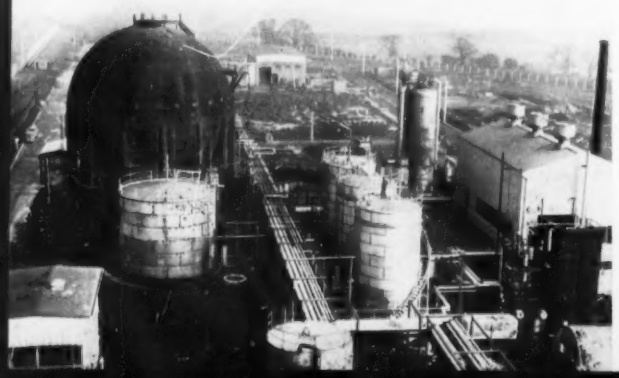
UNITED KINGDOM

Stanford-le-Hope in operation

Messrs. Fisons Limited are to start production early in March at their new nitrogen fertilizer plant at Stanford-le-Hope on the Thames estuary. Work on the construction of this plant, involving a capital investment of over £4 million, began in April 1957 and is being carried out by Constructors John Brown in association with the Chemical and Industrial Corporation of Nassau, Bahamas. The plant will be officially opened on 9th June by Sir James Turner, President of the National Farmers' Union.

Ammonium nitrate in the form of an 86% solution will be manufactured at Stanford-le-Hope by the catalytic oxidation of ammonia to nitric acid, which is then neutralised with more ammonia. The plant will have an annual capacity of about 140,000 tons of ammonium nitrate (49,000 tons N). Anhydrous ammonia will be pumped to the new works from the adjacent plant of the Shell Chemical Co. and will be stored in a Horton sphere with a capacity of 2,000 tons and the largest of its kind in the United Kingdom. Once the plant has been started up energy requirements will be met by heat recovered from burning ammonia with the addition only of small quantities of electricity required to drive pumps.

General view of the Stanford-le-Hope ammonium nitrate plant.



Hot ammonium nitrate solution, containing 35% N, will be distributed to eight Fisons' factories in the United Kingdom by a fleet of road tankers and railway wagons equipped with steam coils to keep the solution above its freezing point of 85°C. Ammonium nitrate produced at Stanford-le-Hope will be used by Fisons in the manufacture of concentrated compound fertilizers.

KayNitro and Magnesium Nitra-Shell

Two new nitrogenous fertilizers, KayNitro and Magnesium Nitra-Shell, are now available in the United Kingdom. Imperial Chemical Industries have introduced KayNitro, a new granular compound fertilizer manufactured by their Billingham Division and containing 16% nitrogen and 16% potash, but no phosphate. It is intended for use on land which needs no phosphate or which has been well treated with basic slag or superphosphate.

KayNitro's most important use should be on the hundreds of thousands of acres of grassland in the United Kingdom which are dressed with basic slag each year. Experiments have shown that the use of nitrogenous fertilizers in intensive grass production must be balanced by regular dressings of potash, particularly when heavy crops of grass are cut for hay and silage. Other agricultural uses for KayNitro are on cereals and green crops adequately supplied with available phosphate. KayNitro stores well, is easily applied and is delivered at £26 17s. 6d. a ton, less the current subsidy.

Magnesium Nitra-Shell is the first top dressing fertilizer containing both magnesium and nitrogen to be sold in the United Kingdom. Marketed by the Shell Chemical Co., the new fertilizer contains 20.5% nitrogen and 7% magnesium oxide specially prepared from dolomitic limestone. The problem of magnesium deficiency in crops and grassland is a subject attracting considerable attention on account of the very heavy rainfall which has caused losses of magnesium through leaching. Delivered to the nearest railway station in six-ton lots, Magnesium Nitra-Shell will cost £27 8s. 6d. per ton less the current subsidy of £9 14s. 9d. per ton.

Shell Chemicals Ltd. have also recently announced a new grade of Nitra-Shell with an increase in nitrogen content from 20.5% to 23% plus 31% calcium carbonate sold in six-ton lots at £26 10s. 0d. a ton. The new grade is being made in limited quantities but larger amounts are to be imported in the spring.

New Nitroglycerine Plant for I.C.I.

After 40 years' production, a nitroglycerine plant of Imperial Chemical Industries at Ardeer has been shut down and is being replaced by a new plant due to go into operation early this year.

The process to be used is similar to that now functioning in a pilot plant in Sweden in which glycerine and nitric acid are reacted in an injector. An emulsion of nitroglycerine and concentrated nitric acid thus obtained is passed into a centrifuge which separates the nitroglycerine and the acid. This process affords great safety of operation as the resulting nitroglycerine is always in diluted form. The centrifuges, which are operated from a distance, are housed in buildings of reinforced concrete surrounded by a wall of earth. I.C.I. have now supplemented their Biazzi process plant controlled by television with a similar plant controlled by a system of mirrors and will be in a position to evaluate both methods.

Blaw-Knox Form a New Company

The formation has recently been announced of Blaw-Knox Chemical Engineering Company Ltd. with offices at 20 Eastbourne Terrace, London, W.2. The new company will be able to call upon the considerable experience of its affiliate, Blaw-Knox Company of Pittsburg, Pa., U.S.A., in low temperature separation processes and the design and construction of nitrogen and nitrogen fertilizer plant.

Among plants erected by The Chemical Plants Division of Blaw-Knox Company are the recently completed nitrogen plant near Provo, Utah, for the Geneva Division of The United States Steel Corporation, a 100-ton per day synthetic ammonia plant for The Lion Oil Company at Eldorado, Arkansas, and a complete nitrogen fertilizer plant for Guanos y Fertilizantes de Mexico, S.A.

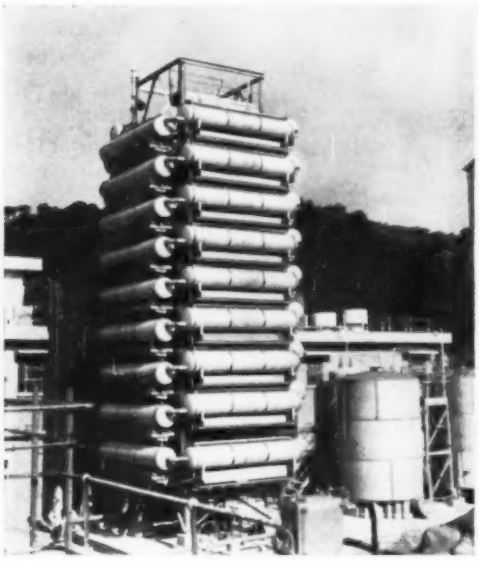
INDIA

Explosives at Gomia

The first commercial blasting explosives factory to be built in India was opened on 5th November 1958 at Gomia, Bihar, by the President of India, Dr. R. Prasad. The factory has been built for Indian Explosives Limited, a company in which I.C.I. Limited, through their Indian subsidiary, are in partnership with the Government of India. Designed, erected and put into operation by the Nobel Division of I.C.I., the factory has a capacity of 5,000 short tons of explosives a year and plans are already being made to increase this capacity to 7,500 tons a year. Many of the raw materials used at Gomia are supplied from other factories nearby. The Konar Dam, a few miles up the River Ganges, provides a controlled supply of water, whilst electric power is supplied by the Bokara thermal power station which is only 10 miles downstream. Liquid ammonia is provided by the fertilizer factory at Sindri, while glycerine is supplied by soap manufacturers in Calcutta.

A hill, 400 feet high, divides the factory area into two. In the non-danger area sulphuric acid, nitric acid and ammonium nitrate are produced. Also in this area are units to concentrate acids and to denitrate waste acid from the nitration plant, together with a laboratory and equipment for making wooden cases, paper shells and the preparation of non-explosive ingredients. The explosives processing is carried out in the danger area, where nitroglycerine is manufactured by the Biazzi process. Mixed acid and glycerine are fed continuously in accurate proportions into a "nitrator," where very rapid reaction takes place and the mixture overflows to a separator where the heavier waste acid is run off, while the nitroglycerine overflows to a series of washing vessels for purification. The nitrator is cooled by brine at $-2°C$ provided by a refrigeration plant. The plant has an automatic security system incorporating the most up-to-date visual and audible warning methods and there is provision, in the case of a serious hazard, for the discharge of all the nitroglycerine into a large volume of water. Mixing

purified nitroglycerine with solid ingredients and the subsequent packing of cartridges, etc., follows conventional lines.



Recently completed by Chemical Construction (G.B.) Ltd., the nitric acid plant at Gomia has a daily capacity of 10 long tons.

When in full production the Gomia factory will be able to meet much of India's demand for explosives needed for mining, quarrying, road and railway building, irrigation and hydro-electric schemes.

Nitrate deposits in Bihar

Extensive deposits of natural nitrates have been found in Bihar and it is planned to erect an experimental plant to investigate their commercial possibilities and methods of processing which would entail purification.

Japanese Combine competing for Neyveli contract

The Japan Plant Association's bid for the £15 million contract in respect of the nitrogen works at Neyveli in Madras State is reported to be receiving favourable consideration. The Association is a consortium of five firms, Toyo Koatsu Industries Inc., Showa Denko, Hitachi, Taisei Construction and the Mitsui Shipbuilding Co. Several United States and European firms, including Società Montecatini, have made bids for the contract.

The Neyveli project involves the construction of plant with an annual production capacity of 94,000 tons of ammonia and 152,000 tons of urea based on the use of lignite and it is planned that the works should go into operation next year.

PAKISTAN

Urea Plants to be Built

Two urea plants are being built by the Pakistan Industrial Development Corporation, one at Fenchuganj in the North of East Pakistan and the other at Multan in West Pakistan. Situated twelve miles south of the Pakistan Petroleum Company's natural gas field at Sui, the Fenchuganj plant is being built for the Pakistan Industrial Development Corporation by the Kobe Steel Company of Japan. It was originally proposed that this plant should be built at Dacca, the capital of East Pakistan, but the project was abandoned since it would have necessitated laying a 145-mile pipeline from the Sylhet gasfield to Dacca. Using Sylhet natural gas, the plant is expected to produce 106,560 long tons of urea and is due for completion in July 1961 at an estimated cost of Rs. 15 crores (U.S. $30 million).

The pipeline now being laid by the Sui Gas Transmission Company of Karachi from the Sui gasfield to Multan will supply the second urea plant. The Multan fertilizer factory is being built by a French group of plant constructors headed by Société Ensa. This company was formed in September last year by the Batignolles-Chatillon and Citra-Enterprises Schneider concerns and has since been joined by Schneider et Cie, the Société des Forges at Ateliers du Creusot, the Material Electrique Sud-Ouest and the Union Européene Industrielle et Financiere. The Ensa group is the principal contractor for the Multan project, estimated to cost U.S. $32 million, but three other firms, St. Gobain, the Société Chimique de la Grande Paroisse and the Société Potasse et Engrais Chimique, will be very closely associated. General engineering of the project will be in the hands of St. Gobain.

The Multan plant will have a capacity of 200 tons of ammonia a day synthesised by the process developed by the Société de la Grande Paroisse, and approximately half the ammonia produced will be used in the manufacture of 59,000 tons a year of urea by the Inventa process, the remainder being used to produce ammonium nitrate.

When in operation these plants will play an important part in meeting Pakistan's growing demand for fertilizers and it is possible that in addition they will subsequently provide urea for the manufacture of plastics.

The first fertilizer plant in Pakistan was built at Daudkhel and was opened on 22nd February 1958. Built with American financial assistance at a cost of Rs. 80 million, it has an annual capacity of 50,000 tons of ammonium sulphate. Installations at this plant include Lurgi gasifiers and oil waste system, a Bamag unit for removal of H_2S and a 40 ton per day ammonia synthesis unit. Ammonium sulphate production at Daudkhel is based on the use of gypsum.

When all these plants are in operation they will play an important part in meeting Pakistan's growing demand for fertilizers and it is possible that subsequently supplies of urea will be available for plastics manufacture.

UNITED STATES

Urea for California

The Hercules Powder Co. have recently put into operation at Hercules, California, their new urea plant which has an annual capacity of 20,000 tons. About 75% of the production at this plant will be used in the manufacture of UN-32, a liquid fertilizer with a nitrogen content of 32% made up 35% of urea and 45% of ammonium nitrate. This fertilizer is suitable for direct foliar application, for combination with certain weed killers or for acceleration of composting. The remaining 25% of the urea produced at Hercules will be used for cattle feed and in the manufacture of urea-formaldehyde resins for the plywood and particle board industry.

Urea plant for SunOlin

Negotiations have recently been completed between the SunOlin Chemical Company and The M.W. Kellogg Company of New York for the design and construction of a urea plant, a steam methane reformer and auxiliary facilities at Claymont, Delaware.

The SunOlin Chemical Company has been formed by the Olin Mathieson Corporation and the Sun Oil Company and the 13½ acre site on which the new plant is to be built is adjacent to Sun Oil's refinery at Marcus Hook, Pa., which will supply the necessary ammonia. Carbon dioxide will be produced in a steam methane reformer which will be built and operated by SunOlin on the new site. In addition, the steam methane facilities will produce approximately 10 million cubic feet of hydrogen a day which will be sold to the Sun Oil Company for production of ammonia and other uses.

The synthetic ammonia plant at Marcus Hook was built in 1955 and has a capacity of 300 tons a day using hydrogen recovered from the catalytic reformers at the refinery. The new plant at Claymont will have an annual capacity of 73,000 tons of urea and will be the fourth plant in the United States to use the Montecatini process. The urea produced will be sold through the Olin Mathieson Chemical Corporation's existing marketing organisation which will act as exclusive sales agent for SunOlin. Work on the new plant is due to start in March 1959 and it is expected that it will go into operation before the end of the year.

Increased Ammonia Capacity

The capacity of the ammonia facilities at the Lawrence, Kansas, works of Co-operative Farm Chemicals will be considerably expanded when extensions now in progress are completed at the end of the summer. Units are also being installed which will add urea and urea-ammonium nitrate solutions to the products of the Lawrence works.

At present, Co-operative Farm Chemicals operate an ammonia plant with an annual capacity of 60,000 tons built by Foster Wheeler Corporation in 1954. Ammonia is used in a nitric acid plant with an annual capacity of 72,600 tons and in an ammonium nitrate plant

with a capacity of 83,000 tons a year. Ammonia is also used in the production of some 13,000 tons of nitrogen solutions a year.

The current extensions will raise the ammonia capacity at Lawrence to 94,000 tons a year and provision is being made for this to be increased by a further 30,000 tons a year when necessary. The urea plant will have an annual capacity of 10,000 tons which will be used in the manufacture of some 23,000 tons of urea-ammonium nitrate solutions. Also included in the extensions are additional storage facilities for 15,000 tons of anhydrous ammonia. The new units at Lawrence have been designed and erected by the Chemical Construction Corp. and are expected to come into operation in August.

California Spray Chemical to sell in Pacific Northwest

The California Spray Chemical Corp. is to extend its operations to the States of Washington and Oregon. In September 1958 it announced that it would build a nitrogen fertilizer works at a cost of $4.6 million at Kennewick, Washington. Due for completion by the end of this year, these works will use ammonia from the nearby Finley works of the Phillips Pacific Chemical Co. to manufacture ammonium nitrate, in both solid and solution form, and high analysis complex fertilizers.

Ammonia from lignite

A new company, North Dakota Nitrogen Inc., has recently been formed to build a nitrogen fertilizer factory near Bismark, North Dakota. The Chemical and Industrial Corp. of Cincinnati have been awarded a contract as consulting and construction engineers for the project. Involving an outlay of $15 million, the new plant will have an annual capacity of between 150,000 and 170,000 tons of fertilizer material and is to be completed within two years. It is planned to use lignite for the production of ammonia synthesis gas.

French Nitrophosphate Process

The Vitro Engineering Co. of New York has recently been licensed to used a process developed by Société d'Auby, Paris, for the nitric acidulation of phosphate rock. This process differs from other nitrophosphate principally in the way it neutralises the acidulation mass and gets rid of hygroscopic calcium nitrate. The use of a solid neutralizer consisting of recycled product fines which have been saturated with ammonia affords a reduction in the number and cost of neutralization vessels, while still avoiding the reversion of soluble phosphates to insoluble tricalcium phosphate. As soon as calcium nitrate forms in the acidulation stage, ammonium sulphate or potassium sulphate is added to the charge.

The Auby process is used in four European plants with capacities ranging from 440 to 1,100 tons a day. In the United States keen interest was shown in nitric acidulation processes during the sulphur shortage of 1950-51, but before there was any substantial change to nitric acid plentiful supplies of sulphur became available once more and fertilizer manufacturers were content to rely on the simpler, conventional superphosphate processes. However, nitrophosphate plants were built by Allied Chemical and Dye at South Point, Ohio, Associated Cooperatives at Sheffield, Ala., and by California Spray-Chemical at Richmond, Calif. Nitrophosphate capacity in the United States is now at an annual level of 100,000 tons N.

Nitrogen for Rocket Fuels

Nitrogenous fuels for rockets and missiles will be supplied by six new plants planned, under construction or recently completed in the United States. The HEF Company of Columbus, Miss., has started the construction of a plant for the manufacture of several million pounds a year of ammonium perchlorate, a product used in solid fuels for rockets and missiles. Ammonium perchlorate is also produced at the recently completed works of the Pennsalt Chemical Corporation at Portland, Oregon, where a 20-ton per day Casale ammonia unit is in operation.

Two new plants designed to meet the requirements of missile production are under construction for the Linde Company Division of the Union Carbide Corporation. A plant to produce 300 tons a day of liquid nitrogen and oxygen for missile factories on the West Coast is under construction at Pittsburgh, California. The first phase of this project is being built

by the Eichleay Corporation and is due for completion in June 1959 with the remaining units coming into operation early in 1960. Another plant to produce nitrogen, oxygen and argon is being built by Linde at Huntsville, Alabama, near the Redstone missile arsenal. In addition to the plants under construction, the Linde Company have recently commissioned new supply facilities at Tulsa, Oklahoma and Houston, Texas, which will be used to store large quantities of liquid nitrogen. The installations at Houston have a capacity of more than one million cubic feet of nitrogen an hour and are a very important source of supply in the Gulf area.

The Hercules Powder Company has recently commissioned a pilot plant at Hercules, California, for the production by a process developed by the company of nitrogen tetroxide, an important rocket propellant. This company is building another plant on a 500-acre site at Bacchus, Utah, where they will employ the latest methods in casting double-based solid fuels for long-range missiles. It is believed that nitrocellulose and nitroglycerine will be the principal components of these fuels. Work on yet another plant for Hercules may start in the near future, for the company have optioned a 1,800-acre site on the shores of Delaware Bay, about one mile north of Lewes. Although no immediate plans have been announced for this site, Hercules have said that they want to be prepared for future expansion in this area.

CZECHOSLOVAKIA

Nitrogen project at Sala

Plans for a major expansion of Czechoslovakia's chemical industry by 1965 include the erection of a large nitrogen plant at Sala in southern Slovakia. Production at this plant with an annual capacity of some 75,000 tons of nitrogen would be based on the use of natural gas and although principally in the form of fertilizer material, might also be used in the manufacture of plastics and detergents.

The new ammonium sulphate works at Zilina in north western Slovakia has recently started trial operations and is expected to go into full production in the near future.

In 1951, Czechoslovakia produced some 30,000 tons of nitrogen in the form of fertilizers and this was increased to 60,500 tons in 1955 and 74,000 tons in 1957. If the plans for the Sala plant materialise, Czechoslovakia could double her production of nitrogen fertilizers and make herself independent of external supplies.

EGYPT

Assuan Nitrogen Project

Work on the construction of the 400,000 tons per year nitrogen fertilizer plant now being built near the Assuan dam, at a cost of £15 million is reported to be so well advanced that it may be possible to start production in 1960, and it has already been decided to build extensions to the capacity. The plant is being built by a consortium consisting of the German

Artist's impression of the Assuan plant.

firms Badische Anilin and Soda Fabrik of Ludwigshafen and Friedrich Uhde G.m.b.H. of Dortmund and the French firm Compagnie Industrielle de Travaux (CITRA) of Paris. 55% of the plant for the project is being supplied by B.A.S.F., 27% by Uhde and the balance by the French firm.

With an initial capacity of between 370,000 and 400,000 tons a year of calcium ammonium nitrate, the Assuan works will be able to meet about two thirds of Egypt's domestic fertilizer consumption. It will be operated by the Société Egyptienne des Produits Chimiques and will use limestone available from nearby quarries while electricity, the bulk of which will be consumed in the electrolytic

hydrogen plant, will be supplied from the hydroelectric power station now under construction at the dam.

The consortium responsible for building the first section of the plant has been awarded the contract to erect the extensions, estimated to cost £3¼ million, which will raise the capacity of the Assuan works by about 120,000 tons of ammonium nitrate a year by 1961, making Egypt virtually independent of foreign supplies.

FINLAND

Nitrogen Fertilizer Operations

Reports that Typpi Oy has shut down its compound fertilizer plant have been denied by the company and it appears that production at the Oulu factory, 140 miles from the Arctic circle, has been maintained during 1958 at a high level, near capacity. The company's production target for that year, 32,000 tons N, was reached on 6th December and the rate of operation is being maintained. Typpi Oy are licensed to produce 400 tons a day of the compound fertilizer 13-11-13 by the nitro-carbonic process of Potasse et Engrais Chimique. Calcium ammonium nitrate is the principal product at Oulu and capacity for this material now totals 100,000 tons a year. Ammonia production is based on the use of Upper Silesian coal and crude oil and the plant is also equipped to handle Bunker C oil. About 20% of the ammonia produced is processed to ammonium sulphate, the remainder being used in the manufacture of calcium ammonium nitrate and the compound fertilizer 13-11-13. Typpi Oy, a government-owned firm, is capable of meeting about 80% of Finland's requirements of nitrogen fertilizer.

WESTERN GERMANY

Capacity expanding

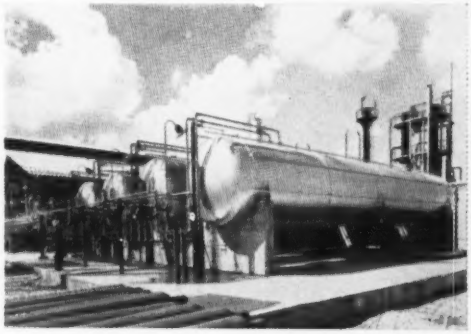
Ruhroel-Chemie, a subsidiary of Matthias Stinnes A.G., is expanding its ammonia synthesis facilities in which coke-oven gas supplied by the parent company is used as the source of hydrogen in a plant with an annual capacity of 63,000 tons N. Extensions now in progress include the installation of a multi-stage cooler within the high pressure compressors, additions to the coke gas separation plant, carbon dioxide washing tower and a high pressure compressor. When the new units come into operation later this year Ruhroel-Chemie will have an annual capacity of some 100,000 tons of anhydrous ammonia. The ammonia produced at this plant will be converted to ammonium sulphate by other producers in the Ruhr, but part may be sold as such.

ISRAEL

Nitric Acid Plant on Stream at Haifa

Production started, towards the end of 1958, at the Haifa plant of Fertilizers and Chemicals Ltd. which has an annual capacity of 22,000 tons of 58% strength nitric acid. The nitric acid produced will be used in the manufacture of ammonium nitrate in a new unit which the Company is to commission in a few months time.

Using ammonia produced at the plant commissioned at Haifa in 1956 the nitric acid unit has been designed by La Société Belge de l'Azote in co-operation with the engineering staff of Fertilizers and Chemicals Ltd. Hitherto ammonium sulphate has been the principal type of nitrogen fertilizer manufactured at Haifa and production has been at the level of 40,000 tons a year.



Ammonia storage tanks at Haifa.

POLAND

Expansions to nitrogen capacity

Extensions to the nitrogen fertilizer plant at the Kedzierzyn Chemical Combine in Silesia are nearing completion. The first sections of the plant, which has an annual capacity of

58,000 tons of nitrogen, were put into operation in July 1958 and output will be in the form of ammonium sulphate, ammonium nitrate or both.

Polish nitrogen capacity is now at an annual level of 230,000 tons, originating principally at the plants at Tarnow, Laziska and Wyry. At Tarnow facilities were installed by Società Montecatini in 1930 with a capacity of 44,000 tons of ammonia a year, based on the production of hydrogen from water gas, and 50,400 tons of ammonium sulphate. It is now planned to use natural gas in an expansion project at this works. Ammonium sulphate is manufactured at Laziska in a plant with annual capacity of 43,000 tons erected by Montecatini in 1932, while anhydrous ammonia is produced at Wyry in a 9,000 tons per year plant installed by Montecatini in 1930.

CUBA

New Fertilizer Project

Anhydrous ammonia is to be manufactured in addition to other chemicals by the Compania Cubana del Nitrogeno S.A., and production will start this year. The new plant is being built in the industrial city of Matanzas near the rayon plant operated by Industrias Consolidadas de Matanzas S.A. Installations to produce anhydrous ammonia, urea and ammonium sulphate are being built by Oronzio de Nora of Italy and The Chemical and Industrial Corporation of Cincinnati, Ohio, are erecting plants for nitric acid and ammonium nitrate.

It is reported that the capacities of the individual units will be as follows:

	short tons per day
Ammonium nitrate	180
Ammonium sulphate	175
Anhydrous ammonia	125
Nitric Acid	150
Nitrogenous solutions	150
Urea	50

The raw materials to be used at the Matanzas plant, which include fuel oil residues, will be obtained from the recently expanded refinery operations in Cuba and will be supplemented by imports. The sulphuric acid required at the plant will be supplied from the production if the new Rometales plant new under construction at Santa Lucia, Pina del Rio Province.

At present Cuba relies on foreign sources for materials used in the preparation of fertilizers and imports small quantities of mixed fertilizers. Consumption of nitrogen is now at a level of 21,000 tons a year, mainly in the form of ammonium sulphate, and it would appear that when the new plant is fully in operation Cuba will be independent of external supplies.

BRAZIL

Japanese Firm to Build Plant at Salvador

A nitrogen plant, with an annual capacity of 30,000 tons of anhydrous ammonia is to be built by Toya Koatsu of Tokyo for Nitrogenio S.A. near the Mataripe refinery at Salvador in Bahia State. Nitrogenio is owned jointly by Bracepa S.A. of Sao Paulo and Chemische Holding A.G. and Chemical Credit and Trading Corporation, both of Zurich. Based on the use of natural gas as a source of hydrogen, the plant is to produce nitric acid, ammonium nitrate, calcium nitrate and possibly urea.

The Government is endeavouring to set up a nitrogen fertilizer industry to make Brazil independent of external supplies, which have been mainly in the form of Chilean nitrate. Foreign firms have been encouraged to participate and the new plant at Salvador will be one of a series of Japanese-Brazilian projects amounting to $100 million.

CHILE

Exports of nitrate to China

Communist China has offered to buy the whole production of the San Martin nitrate mine, in Antofagasta province, for the next five years. The rate of production at this mine is 100,000 tons a year. The government nitrate monopoly has allocated a sum of 400 million peso (£150,000) to modernize the San Martin facilities.

Chilean nitrate production is estimated to have totalled 1.3 million tons during 1957/58 and practically all was sold. Domestic consumption accounted for about 75,000 tons.

Nitrate concession

Concessions to mine nitrate deposits in the Province of Tarapaca have recently been granted to two companies; Cia Salitrera de Tarapaca y Antofagasta and Luis de Urruticoechea. The former company has received two concessions. One covers nearly a million square metres and is estimated to contain 350,000 tons of nitrate, of which 97% is sodium nitrate. The other covers an area of 12½ million square metres and contains a deposit bearing 850,000 tons of nitrate. The firm of Luis de Urruticoechea has obtained a concession covering an area of 3⅓ million square metres containing a deposit bearing 88,000 tons of nitrate. These concessions have been granted for a period of ten years and the companies will pay royalties amounting to 20% of the value of the nitrates they export.

The Government has concluded an agreement with the Cia. Salitrera de Tarapaca y Antofagasta—after the Anglo-Lautaro Company the largest Chilean nitrate producers—whereby it will provide, directly or indirectly, resources to permit the company to maintain its activities and continue its modernisation programme in return for undertakings that the company will:—

(a) keep the present uneconomic "Shanks" plants in operation until modernisation and expansion plans at other plants have permitted it to absorb the labour force at the former;

(b) develop its iron ore mines and liquidate its other investments so as to provide financial resources for the development of its nitrate interests;

(c) submit its technical, financial and economic plans to the Government, within three months, for the latter's approval.

This agreement will go some way towards finding a permanent solution to the company's difficulties. Its present uneconomic activities have only been kept alive by the injection of Central Bank loans and the negotiation by the government of bilateral agreements with other countries giving import privileges in return for undertakings to buy nitrate. Because of the difficulty of finding alternative work for the company's labour, the government has, however, been reluctant to withhold this assistance.

PERU

First Synthetic Plant Completed

The first synthetic nitrogen plant to be built in Peru has recently come into operation. Owned by Fertilizantes Sinteticos S.A. and built at the port of Callao, the new plant uses up to 45 tons of fuel oil per day which is gasified by the Montecatini process. Energy is provided by gas turbine power using Peruvian coal.

It is intended that the annual production of the plant should be 25,000 tons of ammonium nitrate and 15,000 tons of ammonium sulphate for agricultural use, 5,000 tons of industrial ammonium nitrate and 1,500 tons of concentrated nitric acid for manufacturing explosives. The plant will also supply up to 1,000 tons a year of anhydrous ammonia, with a nitrogen content of 50%, for use by the Peruvian chemical industry.

CHINA

Increased capacity

As part of China's intensive drive to increase her production of synthetic fertilizers, work is in progress on the construction of four large nitrogen plants at Tientsin, Chuchow, near Urumchi in Sinkiang province and at Kirin.

At Tientsin one of the largest chemical plants in China is now under construction and when completed in 1961 it will have an annual capacity of 320,000 tons of ammonium chloride and an equal amount of soda ash. The Hou process will be used and will enable both products to be manufactured simultaneously and, according to the New China News Agency, this will afford a saving in production costs of between 36 and 40% compared with the separate manufacture of ammonium chloride and soda ash. This process was developed by the Chinese chemist Hou Teh-pang, now Deputy Minister of the Chemical Industry, and was first applied after

the Communists came to power at the Dairen chemical plant.

The first nitrogen plant in Sinkiang province in the extreme west of China is now being built by the Army. It is to go into partial production this year and will manufacture 40,000 tons of nitrogen fertilizer and 10,000 tons of synthetic ammonia, but this production may be doubled when the plant is fully in operation. The nitrogen plant now under construction at Chuchow in Hunan province in Central China is to come in full operation during 1960 and will have an annual capacity of 220,000 tons of fertilizer material.

Work is still in progress on extensions to the important new chemical complex built on the River Sungari at Kirin in North-Eastern China. The fertilizer factory, which came into operation in 1958, has an annual capacity of 300,000 tons of ammonium nitrate and is the most modern of its type in China. This plant, like several others in China, was erected with considerable help from the U.S.S.R. and is now playing an important part in meeting China's fast growing demand for chemical fertilizers.

INDONESIA

Plans for Urea Plant

The Indonesian Government has contacted several United States contractors and is negotiating with the U.S. Export-Import Bank for the erection of a urea plant with an annual capacity of 100,000 tons. The plant would be built at Palembang in Southern Sumatra and it is hoped to bring it into operation in 1961 or 1962. At present Indonesia's requirements, some 25,000 tons nitrogen a year, are mainly in the form of ammonium sulphate and are wholly imported.

Talks are also in progress with the Soviet Union for the delivery of a superphosphate works and it appears that the Indonesian Government hopes to achieve self sufficiency in fertilizer materials by taking the best of both worlds.

SOUTH KOREA

Chung-Ju project nearing completion

The nitrogen fertilizer plant under construction at Chung-Ju on the Han River in South Korea is nearing completion and should come into operation this summer. Designed for an annual capacity of 85,000 tons of urea using the Inventa process, the plant has been built largely with American aid through the U.S. International Co-operation Administration. The design, engineering and construction of the project are being undertaken jointly by F. H. McGraw and Co. and Hydrocarbon Research.

There has been a certain amount of criticism of this project and in several aspects this would appear to have been justified. The contract to build the plant was originally signed with McGraw-Hydrocarbon in May 1955, but progress at the plant has been considerably delayed while the cost, originally estimated at $22,555,000, will in fact amount to $34,000,000. The site, in very mountainous country only about 70 miles south of the frontier with North Korea, was originally chosen by the South Korean Government as it was hoped to utilize local coal deposits. However, it is believed that some difficulties have arisen over the use of coal—the plant would require about 500 metric tons a day—and oil may have to be brought from the nearest seaport at a cost of $1,000,000 a year. The plant is also being built at a considerable distance from the important agricultural area of southern Korea where the bulk of its production will be used.

The Chung-Ju plant will, however, play an important part in meeting South Korea's considerable demand for nitrogen fertilizers, now amounting to some 156,000 tons nitrogen a year, and will save the country about $10 million a year in foreign exchange.

The South Korean Government is planning to build a second urea plant at Nanju of similar capacity to the Chung-Ju plant and estimated to cost $23,500,000. This project, for which competition between German and U.S. plant constructors has been severe, has been entrusted to a group of West German firms including Demag of Duisburg, Lurgi of Frankfurt a/M and Siemens and Halske of Berlin. The start of the erection of this plant has been repeatedly delayed by the vacillations of the South Korean Government.

Statistical Appendix

United States

PRODUCTION

Short Tons

	Anhydrous Ammonia	*Ammoniating Solutions**	*Ammonium Nitrate*		*Ammonium Sulphate*		*Nitric Acid*	*Urea*
			Total	Fertilizer	By-Product	Synthetic		
1958 January ...	321,937	40,578	235,731	213,554	57,759	83,451	247,989	46,275
February ...	296,736	50,446	203,472	181,676	48,375	80,777	209,121	75,060
March ...	339,015	64,364	240,785	217,501	53,001	101,116	245,543	4,153
April	329,837	82,337	231,228	208,512	48,793	97,603	235,477	44,207
May	348,158	62,092	186,417	167,122	49,148	104,410	210,050	45,249
June	336,309	35,429	154,204	139,007	49,328	97,917	175,535	39,045
July	294,669	30,283	176,748	162,311	48,019	85,776	191,792	39,599
August ...	280,581	40,161	184,742	166,244	50,114	84,231	196,916	
September ...	304,753	56,088	208,760	186,150	51,526	92,583	223,748	
October ...	321,392		229,357				251,456	

* 100% N

Belgium

PRODUCTION

Metric Tons

	Synthetic Ammonia		*By-product Ammonium Sulphate*	*Fixed Nitrogen for technical use*	*Compound Fertilizers*	
	Total N content	Fertilizer N content	N content	tons product	tons product	N content
1957 January	17,295	13,412	1,504	804	16,840	1,066
February	15,634	13,603	1,372	637	15,096	1,401
March	19,183	15,782	1,492	1,171	20,153	1,597
April	20,542	18,322	1,391	740	15,182	1,263
May	21,125	18,776	1,396	555	8,021	840
June	18,210	16,347	1,280	703	8,079	770
July	16,201	14,567	1,549	588	9,040	711
August	22,166	19,793	1,520	733	12,837	799
September	20,062	18,044	1,362	571	13,614	994
October	21,628	19,777	1,379	503	11,384	798
November	20,366	18,525	1,306	565	11,582	925
December	21,285	19,628	1,451	465	15,159	752
1958 January	21,786	19,732	1,445	547	19,332	1,581
February	19,870	18,181	1,344	447	24,340	2,025
March	23,035	20,810	1,466	407	22,789	2,162
April	21,043	18,811	1,437	710	23,502	2,471
May	23,850	21,688	2,005	532	15,036	1,668
June	23,186	21,248	1,439	492	16,661	2,097
July	22,009	19,922	1,443	459	7,974	770
August	23,754	19,001	1,556	601	17,470	1,752
September	23,921	21,542	1,573	485	21,282	1,649
October	24,010	21,987	1,556	613	29,014	1,990

EXPORTS 1958

AMMONIUM NITRATE

Metric Tons Product

	Jan.-March	*Jan.-June*	*Jan.-Sept.*
Total	121,689	190,986	254,819
Netherlands ...	—	20	20
Portugal	2,188	2,888	9,394
Yugoslavia ...	45,153	45,153	45,153
China	14,425	24,455	70,168
Egypt	43,002	96,999	180,499

AMMONIUM SULPHATE*

	Jan.-March	*Jan.-June*	*Jan.-Sept.*
Total	150,899	324,190	516,903
Spain	—	—	87,935
Greece	—	5	15,033
Ireland	7,179	8,782	13,882
Portugal	7,767	10,899	14,182
China	23,064	135,819	205,997
South Korea ...	95,237	151,965	115,965
Puerto Rico ...	5,000	14,105	14,105

* Including ammonium sulphate nitrate

West Germany

PRODUCTION

Metric Tons

	Synthetic Ammonia	Fertilizer Nitrogen				Technical Nitrogen
		Total	From Synthetic Ammonia	From Coke Ovens and Gas Works	Calcium Cyanamide	
1957						
1st Quarter ...	246,064	221,440	173,054	27,673	20,749	36,520
1st Quarter ...	257,058	240,572	192,450	27,863	20,259	37,479
2nd Quarter ...	270,160	258,118	207,140	27,931	23,047	36,109
2nd Quarter ...	280,218	253,319	204,452	27,988	20,789	43,009
1958						
3rd Quarter ...	286,889	269,758	219,760	27,146	22,852	41,260
3rd Quarter ...	281,464	266,216	219,915	27,120	19,181	39,285
4th Quarter ...	274,642	272,927	221,218	27,489	24,220	37,836

Italy

PRODUCTION

	Ammonium Sulphate (20-21% N)	Ammonium Nitrate (20-26.5% N)	Ammonium Nitrate (33-35% N)	Calcium Nitrate (13-15.5% N)	Sodium Nitrate (15-16% N)	Calcium Cyanamide (15-16% N)	Urea (44-45% N)
1956	776,250	367,008	11,588	301,239	5,965	123,385	—
1957	65,639	23,980	1,284	22,913	247	4,263	—
January ...	56,878	31,222	770	31,547	240	630	—
January ...	54,355	34,981	998	33,290	579	13,792	—
February ...	57,830	30,637	926	23,175	451	12,393	—
March ...	68,864	26,006	1,500	23,316	550	8,761	—
April	69,585	22,720	845	23,247	532	17,780	—
May	68,782	24,509	845	21,759	491	11,415	—
June	70,378	37,816	991	22,477	752	18,951	—
July	74,091	31,883	1,065	21,310	353	13,117	—
August ...	69,982	28,183	1,067	24,788	664	9,002	—
September ...	61,548	36,646	776	24,604	568	8,704	—
October ...	60,531	37,430	521	32,814	540	4,580	—
November ...	58,368	43,284	666	33,646	703	7,561	7,766
December ...	53,528	41,019	977	26,895	676	6,077	4,813
1958 January ...	57,696	42,970	1,131	30,414	610	11,091	5,535
February ...	59,133	36,239	834	21,584	401	16,662	5,640
March ...	67,784	38,652	937	21,918	438	23,731	5,711
April	67,784	38,652	937	21,918	438	23,731	5,711
May	70,742	35,361	912	23,211	314	29,201	5,252
June	88,363	49,276	957	20,359	509	21,023	3,786
July	90,586	48,782	863	24,813	353	14,690	5,939
August ...	92,823	40,842	1,089	24,804	543	17,873	5,441
September ..	787,028	336,024	13,678	306,832	6,197	201,165	

EXPORTS 1958

AMMONIUM NITRATE

	Jan.-March	Jan.-June	Jan.-Sept.
Total	33,292	92,889	179,147
Greece	5,015	5,015	5,015
Yugoslavia ...	11,569	46,498	54,836
Portugal	3,071	9,396	9,396
Turkey	1,553	1,553	1,553
U.S.A.	9,977	9,977	13,152
China	—	9,018	49,559
Others	2,107	11,432	45,636

AMMONIUM SULPHATE

	Jan.-March	Jan.-June	Jan.-Sept.
Total	76,875	166,234	261,970
Portugal	9,863	11,180	11,180
Turkey	5,454	10,516	10,516
China	10,490	20,490	59,604
South Korea ...	36,311	61,803	69,203
Pakistan	—	34,098	43,676
Others	14,757	28,147	67,751

UREA

	Jan.-March	Jan.-June	Jan.-Sept.
Total	6,953	23,229	37,762
France	570	850	850
China	3,316	8,317	14,317
Brazil	784	904	1,260
Columbia	1,470	1,470	1,617
India	—	9,923	16,718
Others	813	1,765	3,000

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